SALMON AND STEELHEAD HABITAT LIMITING FACTORS

WATER RESOURCE INVENTORY AREA 28

WASHINGTON STATE CONSERVATION COMMISSION

FINAL REPORT

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EXECUTIVE SUMMARY

Section 10 of Engrossed Substitute House Bill 2496 (Salmon Recovery Act of 1998), directs the Washington State Conservation Commission, in consultation with local government and treaty tribes to invite private, federal, state, tribal, and local government personnel with appropriate expertise to convene as a Technical Advisory Group (TAG). The purpose of the TAG is to identify habitat limiting factors for salmonids. Limiting factors are defined as “conditions that limit the ability of habitat to fully sustain populations of salmon, including all species of the family Salmonidae.” The bill further clarifies the definition by stating, “These factors are primarily fish passage barriers and degraded estuarine areas, riparian corridors, stream channels, and wetlands.” It is important to note that the responsibilities given to the Conservation Commission in ESHB 2496 do not constitute a full limiting factors analysis.

This report is based on a combination of existing watershed studies and the personal knowledge of the TAG participants. TAG members mapped fish distribution maps for coho, chinook, and chum salmon, and for winter and summer steelhead in Water Resource Inventory Area (WRIA) 28. Salmonid habitat limiting factors were identified for each major anadromous stream within WRIA 28.

WRIA 28 is located in Southwest Washington, with boundaries that extend to the western margins of the Wind River to the east, the Columbia River to the south, and the East Fork Lewis River to the north (see Map A-1). The inventory area includes the southern and eastern portions of Clark County and southwestern Skamania County. For purposes of this report WRIA 28 was divided into three major subbasins: the Lake River Subbasin, the Washougal River Subbasin, and the Bonneville Tributaries Subbasin. These drainages cover approximately 316,365 acres or 494 square miles and enter the Columbia River between river mile (RM) 87.6, at Lake River, and RM 142.3 near Bonneville Dam.

Three stocks of anadromous salmon, both winter and summer steelhead, and coastal cutthroat trout return to the rivers and streams of WRIA 28. Chinook salmon, chum salmon, and steelhead are listed as “threatened” by National Marine Fisheries Service under the Endangered Species Act. Coho salmon are listed as a candidate species, and coastal cutthroat are proposed for a “threatened” listing.

WRIA 28 Habitat Limiting Factors

There were a number of habitat limiting factors, and recommendations to address these factors, that apply across the entire WRIA including:

- Various land uses practices have negative impacts on habitat conditions for salmonids. If these impacts continue at the existing rate in many of the subbasins of WRIA 28, habitat degradation will outstrip any possible restoration strategy. The TAG suggests that critical areas ordinances be developed and/or updated to ensure protection of critical habitat for threatened and endangered salmonids.
- Stormwater in urban areas contributes to increased peak flows, leading to bed and bank scour and channel shifting. These inputs also contribute fine sediments and

reduce water quality. Where possible, alter stormwater facilities to reduce direct runoff to streams and increase infiltration. Protect and enhance wetlands and other water recharge areas.

- Almost every stream system within WRIA 28 has inadequate levels of large woody debris (LWD). Supplement LWD in appropriate stream channels, to provide short-term habitat benefits. Protect and enhance riparian habitat to increase LWD supplies over the long-term.
- Riparian restoration is needed almost throughout WRIA 28. Many commercial forestlands are in the process of recovering from disturbances early in the last century. Other areas have reduced riparian function due to urban and rural development. Protect existing functional riparian habitat and restore those areas that have been degraded by past activities, starting with productive anadromous tributaries.
- The headwaters of most streams within WRIA contain the vast majority of functional habitat. These areas also provide cool, clean water, spawning sediments and woody debris that help buffer downstream land use activities. Focus on protecting these more pristine habitat reaches from additional land-use impacts.
- Elevated water temperatures are a problem in many stream systems within WRIA 28. Poor riparian conditions, low-flow problems, high width-to-depth ratios, and impounded water all contribute to elevated water temperatures. A comprehensive approach to water quality improvements is needed that addresses all of these related problems across the watershed.
- Water withdrawals, for both industrial and domestic uses, reduce instream flows and the habitat available for salmonids. Explore opportunities to protect and augment stream flows in WRIA 28 during low-flow periods.

Lake River Subbasin

This subbasin includes all streams that drain to Lake River including Salmon, Whipple, and Burnt Bridge Creeks. Most of these streams flow through highly urbanized areas of the City of Vancouver and Clark County. Extensive urban and rural development within the subbasin has degraded habitat in many of the stream systems. Stormwater impacts, loss of forest cover, altered riparian corridors, minimal instream habitat diversity, excessive impervious surfaces, high road densities, channelization and streambank hardening, flood control projects, and passage barriers have all contributed to the degradation of habitat conditions. For each of the following habitat categories the Technical Advisory Group (TAG) developed recommendations for addressing the major habitat limiting factors in the subbasin.

<u>Access:</u>
A number of passage barriers block access to potentially productive salmonid habitat. Assess and prioritize repair and/or removal of these passage barriers. Barriers on Whipple, Packard, and Baker Creeks are significant barriers that need repair.

Floodplain Connectivity:

Diking, streambank hardening, channelization, and channel incision has eliminated access to floodplain habitat and reduced the overwintering habitat in many areas of the subbasin. Substantial amounts of stream adjacent wetland habitats have also been eliminated within the subbasin. Habitat surveys in 1989 determined that the potential spawning capacity within the Salmon Creek watershed is much larger than the actual rearing capacity. Reestablish floodplain connectivity and protect floodplain wetlands, starting with the lower and middle reaches of Salmon Creek, along Burnt Bridge Creek, in upper Mill Creek, and within the Vancouver Lake lowlands.

Streambed Sediment Conditions:

Most stream systems within the subbasin receive excessive inputs of fine sediment. Stormwater, high road densities, and other related impacts from urbanization, agricultural activities, and the loss of riparian vegetation all contribute to sediment problems within the subbasin. Various stream channels within the subbasin, including Whipple Creek, Burnt Bridge Creek, Curtin Creek, and the upper reaches of Mill Creek are largely silt covered with only minimal amounts of spawning substrates. A comprehensive program to address these excessive fine sediment inputs is needed.

Channel Conditions:

Almost throughout the subbasin, functioning Large Woody Debris (LWD) is scarce or absent. Consequently, pool habitat, spawning gravels, and habitat diversity are also scarce. Look for opportunities to enhance pool habitat, spawning habitat, and general habitat diversity by supplementing LWD. First focus LWD supplementation in the upper reaches of Salmon Creek, and Rock Creek where a majority of the quality spawning and rearing habitat in the subbasin occurs.

Riparian Conditions:

Riparian conditions are generally poor throughout the Lake River Subbasin and riparian restoration is needed along almost all streams. Only a few areas within the subbasin have fairly high quality riparian habitat. In general these occur in the upper reaches of Salmon Creek, Rock Creek, and Morgan Creek. Protection and enhancement of this functional riparian habitat should become a high priority.

Water Quality:

Serious water quality problems plague most streams within the subbasin. Elevated water temperatures are the most serious concern in many areas of the subbasin. Poor riparian conditions, low flows, stormwater and road related issues, impoundments, and impervious surfaces all contribute to elevated water temperatures. Water quality improvements will likely need to address all of these contributing factors before substantial improvements will occur.

Water Quantity:

Both elevated peak flows and low flows are considered limiting factors for salmonids in the Lake River Subbasin. Urbanization and other land uses have left almost the entire subbasin hydrologically immature. As such, the streams are likely subjected to increased peak flows that can cause bed and bank scour and channel shifting to the detriment of egg and fry survival. Similar to water quality problems, there are a number of factors contributing to both elevated and low flow problems within the subbasin that will need to be addressed before improvements in streamflow will occur.

Biological Processes:

Escapement for most anadromous fish is well below historic numbers and the lack of carcasses contributing nutrients to stream systems may be limiting production. Additionally, habitat alterations, non-native introductions, and hatchery practices influence competitive interactions and ecological processes in the Lake River Subbasin. TAG members expressed concern over the lack of information on warm water predators and their potential impact on salmonids within Lake River. Also, exotic species like reed canarygrass and Himalayan blackberries have invaded many of the tributaries within the subbasin. The dense canopy and litter layer associated with these species precludes the reestablishment of riparian forest. Remove these invasive species and reestablish native riparian plants wherever possible.

Priority Habitats In Need Of Protection:

- New spawning grounds for chum were recently discovered along the northern Columbia River shoreline near the I-205 Bridge where groundwater upwelling occurs. Identify the extent and condition of these chum-spawning grounds, along with the source of these springs, and protect from the area from future nearshore development and additional groundwater withdrawals.
- The upper reaches of Salmon Creek and Rock Creek provide the majority of quality spawning and rearing habitat in the watershed. Protection of these headwater reaches is the highest priority within the Salmon Creek system.
- Wetland habitat is quickly disappearing in the Lake River Subbasin. Protect and enhance existing wetlands, and identify areas where additional wetland habitat can be restored.
- An analysis of stream habitat and redd surveys determined that the potential spawning capacity within the Salmon Creek watershed is much larger than the actual rearing capacity. Protection and enhancement of potential rearing habitat for coho, steelhead, and/or coastal cutthroat should provide substantially benefit for salmonid production in this stream system.

Washougal River Subbasin

Past natural and anthropogenic disturbances have had significant impacts on habitat conditions within the subbasin. The Yacolt Burn, forestry practices, splash and hydroelectric dams, road construction, mining, residential and industrial development, water withdrawals, and industrial pollution from paper mills have all altered habitat conditions within the subbasin. While some habitat conditions have improved over time, other habitat conditions have been much slower to recover from past impacts.

Many reaches of the mainstem Washougal and its tributaries still lack adequate structural LWD, spawning gravels, and quality pool habitat. Culverts and dams still block passage to critical and very limited tributary habitat. Stream adjacent roads continue to alter riparian function and stream hydrology, and contribute fine sediments to spawning gravels. Water withdrawals continue to limit available spawning and, especially, rearing habitat within the subbasin. Development continues to reduce critical floodplain and riparian functions. Recommendations for addressing the major habitat limiting factors in the subbasin include:

Access:

Steep gradients and numerous falls limit access to critical tributary spawning and rearing habitat in the Washougal River Subbasin. Artificial passage barriers further limit the habitat available. Reopen as much tributary habitat as feasible, starting with the removal or alteration of some major passage barriers such as the dam on Wild Boy Creek.

Floodplain Connectivity:

Floodplain connections have been lost along portions of the mainstem Washougal and its major tributaries. Floodplain development that eliminates critical salmonid habitat is still occurring within the urban areas of Washougal and Camas. Local jurisdictions need to update existing regulations to increase protection of the remaining floodplain habitat. Opportunities for restoration and enhancement of floodplain and side channel habitat occur on the mainstem Washougal River, along the lower reaches of the Little Washougal, in School House Creek, and in Slough Creek.

Streambed Sediment Conditions:

Stormwater inputs, all-terrain vehicle (ATV) use, vegetation control in power line corridors, stream adjacent roads, farming and other land uses contribute excessive fine sediment to stream systems within the Washougal Subbasin. Road related problems are especially apparent in the upper Washougal basin. Recommendations include:

- Local jurisdictions need to review and update erosion and stormwater measures and shoreline regulations to assure protection of aquatic resources from urban and rural development.
- Continue to develop educational programs and incentives programs for landowners to alter various land use activities that negatively impact riparian corridors and increase fine sediment inputs.
- Fence cattle out of stream systems and restore riparian corridors to reduce erosion.
- Restrict ATV use to areas where impacts can be mitigated.

Channel Conditions:

Almost throughout the subbasin, functioning LWD is scarce or absent. The lack of LWD, combined with the hydrologic impacts of the Yacolt Burn and subsequent logging, have left many of the stream channels in the Washougal scoured to bedrock and without adequate spawning gravels or pool habitat. The lack of LWD was considered one of most significant limiting factor in the Washougal Subbasin. Supplementation of LWD is needed in specific areas to provide short-term benefits; however, long-term LWD recruitment is needed to maintain the benefits.

Riparian Conditions:

Riparian conditions are slowly improving within the Washougal River Subbasin, and unlike the more developed Lake River Subbasin, there are some fairly extensive areas with "good" riparian conditions in the Washougal River Subbasin. These areas are almost all located in the upper reaches of the mainstem Washougal and its tributaries on public or private industrial lands. Protection of these somewhat healthy riparian areas is critical to salmon recovery efforts in the subbasin. Restore degraded riparian habitat along the more developed lower reaches.

Water Quality:

While some major water quality issues in the lower river have been largely resolved over the last few decades, various water quality problems continue to plague the watershed. Elevated water temperatures remain a serious concern in many areas of the Washougal River Subbasin. Poor riparian conditions, low streamflows, stormwater and road related issues, impoundments, recreational impacts, and a channel scoured to bedrock all contribute to elevated water temperatures. Only a concerted long-term effort to address these related problems will reduce water temperatures and increase water quality in the subbasin.

Water Quantity:

Both elevated peak flows and low flows are considered limiting factors for salmonids in the Washougal River Subbasin. All but the upper reaches of the subbasin are hydrologically immature. Streams are subject to increased peak flows that can cause bed and bank scour and channel shifting to the detriment of egg and fry survival. Reduction of peak flows requires maintenance of mature forest cover in the subbasin and a reduction in stormwater impacts. Water withdrawals from Jones, Boulder, and Lacamas Lake reduce already low summer streamflow within the Little Washougal watershed and Lacamas Creek. The City of Camas and the Camas paper mill need to reduce the impacts of their water withdrawals on listed salmonids. Low summer flows, combined with high public use above Dugan Falls, also negatively impacts the adult population of summer steelhead through harassing and/or killing of holding fish. Reduce these impacts through increased public education and outreach, additional enforcement of existing regulations, and creation of sanctuaries for steelhead in critical holding areas within the upper Washougal River.

Biological Processes:

Escapement for most anadromous fish is well below historic numbers and the lack of carcasses contributing nutrients to stream systems may be limiting production. Assess the potential for carcass placement projects within the subbasin to increase nutrient levels and potentially productivity. TAG members expressed concerns about warm-water predators in the lower river and the impact of hatchery fish on stocks of summer steelhead within the subbasin. Hatchery operations need to review and update their plans to protect native stocks of salmon and steelhead.

Priority Habitats In Need Of Protection:

- The upper reaches of the Washougal River mainstem and its tributaries contain some of the best, most functional habitat within WRIA 28. Cool, clear water from these reaches buffers downstream impacts to water quality, and somewhat healthy riparian areas provide LWD recruitment to downstream reaches. Protect these streams that provide some of the best remaining habitat for summer steelhead stocks in the lower Columbia River.
- Most of the functional habitat within the Little Washougal River, and the North Fork Washougal also occurs within the headwaters. Protection and enhancement of these headwater reaches will benefit multiple stocks of salmon, steelhead, and coastal cutthroat trout.
- A substantial amount of the floodplain and side-channel habitat within the Washougal Subbasin has been lost or disconnected from the streams. Protection and enhancement of these habitats is critical for salmonids rearing within the subbasin.
- Urban and rural development within the Washougal Subbasin has also substantially increased impervious surfaces and reduced forest cover. Protection and enhancement of existing wetland habitat anywhere in the subbasin would provide multiple benefits for salmonids, especially within the Little Washougal and Lacamas Creek watersheds.

Bonneville Tributaries Subbasin

A number of the Bonneville Subbasin tributaries fall within the Columbia River Gorge National Scenic area and are protected from future development pressure. However, timber harvests, transportation corridors, passage barriers, and rural development have all contributed to habitat degradation in the subbasin, and smaller communities are rapidly developing. Recommendations for addressing the major habitat limiting factors in the subbasin include:

Access:
Most of the streams within this subbasin contain only a limited amount of lower gradient habitat for spawning and rearing of anadromous salmonids, located mainly in the lower reaches. The railroads, State Route (SR) 14, dikes, and other artificial structures reduce or eliminate access to some of the most productive habitat within the subbasin, as well as reduce overall habitat quality. Restore passage, and the natural hydrology and sediment transport within these streams wherever feasible.

Floodplain Connectivity:
There is only a limited amount of low gradient floodplain and side-channel habitat available within the Bonneville Tributaries Subbasin. Transportation corridors and other development along the Columbia have reduced or eliminated already limited floodplain habitat in many of these stream systems. Where possible, increase the amount and quality of floodplain habitat in the lower reaches of these smaller tributaries.

Streambed Sediment Conditions:
Fine sediment conditions within Gibbons Creek and its tributaries are “poor” and likely a major limiting factor. Fine sediments have also accumulated in the spring fed areas of

Duncan Creek. Spawning substrates within the springs need cleaning now that the area is accessible to "threatened" chum salmon. Stream adjacent roads also likely contribute excessive fine sediments to Hardy, Woodward, and lower Duncan Creeks.

Heavy loads of course sediments are deposited where the streams emerge from steep canyons in the Gorge. To some degree this is a natural process, and to some degree these sediment loads have increased due to land use activities and artificial structures within the subbasin. Culverts along SR 14 and the railroads exacerbate this natural condition as they alter or constrict the movement of coarse sediments down through these systems. Restore the natural hydrology and movement of sediments through these stream systems.

Channel Conditions:

Almost throughout the subbasin, functioning Large Woody Debris (LWD) is scarce or absent. Consequently, pool habitat and habitat diversity are also scarce. LWD supplementation in the lower reaches of most stream systems would enhance pool habitat, spawning habitat, and general habitat diversity in the short-term.

Riparian Conditions:

Riparian conditions are poor along almost every stream within the subbasin, especially along the lower reaches with productive anadromous habitat. Protection of existing mature riparian habitat in the upper reaches and restoration of the lower reaches is a high priority within the subbasin. Target riparian restoration efforts along the most productive and/or degraded streams including the lower reaches of Hardy, Hamilton, Lawton, and Woodward Creeks.

Numerous stream adjacent roads reduce riparian functions along Woodward Creek and Duncan Creek. Where feasible, abandon and/or repair these roads to provide at least a minimal riparian buffer along anadromous streams.

Water Quality:

Other than some limited data on Gibbons, Campen, and Hardy Creeks, water quality data is lacking within the Bonneville Tributaries Subbasin. Water temperatures and fecal coliform exceed state standards in Gibbons and Campen Creeks. Ecology is implementing a TMDL process for these creeks to address existing water quality problems. Water quality monitoring is needed for other streams within the subbasin. Protect and enhance riparian habitat in headwater reaches to help reduce downstream water temperatures. Develop stormwater facilities and ordinances in the City of North Bonneville to protect critical spawning habitat for chum salmon.

Water Quantity:

Both elevated peak flows and low flows are considered limiting factors for salmonids in the Bonneville Tributaries Subbasin. Urbanization, forestry, agriculture, and other land uses have left portions of subbasin hydrologically immature. The rapid residential development occurring in the Gibbons Creek watershed and in the City of North Bonneville, adds to already high levels of impervious surfaces and the loss of forest cover along these streams. Encourage land use and development that maintains and enhances forest cover, wetlands, and riparian vegetation, and reduces stormwater impacts.

Biological Processes:

Escapement for most anadromous fish is well below historic numbers and the lack of carcasses contributing nutrients to stream systems may be limiting production. Additionally, habitat alterations and non-native introductions influence competitive interactions and ecological processes in the Bonneville Tributaries Subbasin. Removal of reed canary grass from the Duncan Creek springs and reestablishment of native plant species is a high priority in the subbasin.

Priority Habitats In Need Of Protection:

- Protection of chum spawning areas in Hamilton and Hardy Creeks is one of the highest priorities within the subbasin, as well as in the entire lower Columbia River basin. Protection of these spawning sites requires protection of the headwaters of these streams to maintain good water quality and the natural hydrologic regime, and to minimize fine sediment inputs.
- Chum and fall chinook spawn in the mainstem of the Columbia River just downstream of Bonneville Dam near Ives and Pierce Islands. These spawning sites provide critical habitat for listed chum species in the lower Columbia, especially during dry years when low flows limit the availability to tributary spawning habitat.
- Hundreds of chum salmon once returned to spawn within the spring-fed areas along Duncan Creek. With the construction of a new passage facility, chum salmon again have access to this productive tributary. Protect and enhance of these springs.
- The upper reaches of Gibbons Creek have the potential to support a healthy population of coho and steelhead. Protect and enhance riparian corridors and LWD supplies.

INTRODUCTION

Habitat Limiting Factors Background

The successful recovery of naturally spawning salmon populations depends upon directing actions simultaneously at harvest, hatcheries, habitat and hydro, the 4H's. The 1998 state legislative session produced a number of bills aimed at salmon recovery. Engrossed Substitute House Bill (ESHB) 2496 is a key piece of the 1998 Legislature's salmon recovery effort, with the focus directed at salmon habitat issues.
Engrossed Substitute House Bill (ESHB) 2496 in part:

- directs the Conservation Commission in consultation with local government and the tribes to invite private, federal, state, tribal and local government personnel with appropriate expertise to act as a technical advisory group;
- directs the technical advisory group to identify limiting factors for salmonids to respond to the limiting factors relating to habitat pursuant to section 8 sub 2 of this act;
- defines limiting factors as "conditions that limit the ability of habitat to fully sustain populations of salmon."
- defines salmon as all members of the family salmonidae, which are capable of self-sustaining, natural production.

The overall goal of the Conservation Commission's limiting factors project is to identify habitat factors limiting production of salmonids in the state. At this time, the report identifies habitat limiting factors pertaining to salmon, steelhead trout and includes bull trout when they share the same waters with salmon and steelhead. Later, we will add bull trout-only waters, as well as specific factors that relate to cutthroat.

It is important to note that the responsibilities given to the Conservation Commission in ESHB 2496 do not constitute a full limiting factors analysis. The hatchery, hydro and harvest segments of identifying limiting factors are being dealt with in other forums.

The Role of Habitat in a Healthy Population of Natural Spawning Salmon

During the last 10,000 years, Washington State anadromous salmonid populations have evolved in their specific habitats (Miller 1965). Water chemistry, flow, and the physical stream components unique to each stream have helped shape the characteristics of every salmon population. These unique physical attributes have resulted in a wide variety of distinct salmon stocks for each salmon species throughout the State. Within a given species, stocks are population units that do not extensively interbreed because returning adults rely on a stream's unique chemical and physical characteristics to guide them to their natal grounds to spawn. This maintains the separation of stocks during reproduction, thus preserving the distinctiveness of each stock.

Throughout the salmon's life cycle, the dependence between the stream and a stock continues. Adults spawn in areas near their own origin because survival favors those that do. The timing of juveniles leaving the river and entering the estuary is tied to high natural river flows. It has been theorized that the faster speed during out-migration reduces predation on the young salmon and perhaps is coincident to favorable feeding conditions in the estuary (Wetherall 1971). These are a few examples that illustrate how a salmon stock and its environment are intertwined throughout the entire life cycle.

Salmon habitat includes the physical, chemical and biological components of the environment that support salmon. Within freshwater and estuarine environments, these components include water quality, water quantity or flows, stream and river physical features, riparian zones, upland terrestrial conditions, and ecosystem interactions as they pertain to habitat. However, these components closely intertwine. Low stream flows can alter water quality by increasing temperatures and decreasing the amount of available dissolved oxygen, while concentrating toxic materials. Water quality can impact stream conditions through heavy sediment loads, which result in a corresponding increase in channel instability and decrease in spawning success. The riparian zone interacts with the stream environment, providing nutrients and a food web base, woody debris for habitat and flow control (stream features), filtering runoff prior to surface water entry (water quality), and providing shade to aid in water temperature control.

Salmon habitat includes clean, cool, well-oxygenated water flowing at a normal (natural) rate for all stages of freshwater life. In addition, salmon survival depends upon specific habitat needs for egg incubation, juvenile rearing, migration of juveniles to saltwater, estuary rearing, ocean rearing, adult migration to spawning areas, and spawning. These specific needs can vary by species and even by stock.

When adults return to spawn, they not only need adequate flows and water quality, but also unimpeded passage to their natal grounds. They need deep pools with vegetative cover and instream structures such as root wads for resting and shelter from predators. Successful spawning and incubation depend on sufficient gravel of the right size for that particular population, in addition to the constant need of adequate flows and water quality, all in unison at the necessary location. Also, delayed upstream migration can be critical. After entering freshwater, most salmon have a limited time to migrate and spawn, in some cases, as little as 2-3 weeks. Delays can results in pre-spawning mortality, or spawning in a sub-optimum location.

After spawning, the eggs need stable gravel that is not choked with sediment. River channel stability is vital at this life history stage. Floods have their greatest impact to salmon populations during incubation, and flood impacts are worsened by human activities. In a natural river system, the upland areas are forested, and the trees and their roots store precipitation, which slows the rate of storm water into the stream. The natural, healthy river is sinuous and contains large pieces of wood contributed by an intact, mature riparian zone. Both slow the speed of water downstream. Natural systems have floodplains that are connected directly to the river at many points, allowing wetlands to store flood water and later discharge this storage back to the river during lower flows. In a healthy river, erosion or sediment input is great enough to provide new gravel for spawning and incubation, but does not overwhelm the system, raising the riverbed and increasing channel instability. A stable incubation environment is essential for salmon, but is a complex function of nearly all habitat components contained within that river ecosystem.

Once the young fry emerge from the gravel nests, certain species such as chum, pink, and some chinook salmon quickly migrate downstream to the estuary. Other species, such as coho, steelhead, bull trout, and chinook, will search for suitable rearing habitat within the side sloughs and channels, tributaries, and spring-fed "seep" areas, as well as the outer edges of the stream. These quiet-water side margin and off channel slough areas are vital for early juvenile habitat. The presence of woody debris and overhead cover aid in food and nutrient inputs as well as provide protection from predators. For most of these species, juveniles use this type of habitat in the spring. Most sockeye populations migrate from their gravel nests quickly to larger lake environments where they have unique habitat requirements. These include water quality sufficient to produce the necessary complex food web to support one to three years of salmon growth in that lake habitat prior to outmigration to the estuary.

As growth continues, the juvenile salmon (parr) move away from the quiet shallow areas to deeper, faster areas of the stream. These include coho, steelhead, bull trout, and certain chinook. For some of these species, this movement is coincident with the summer low flows. Low flows constrain salmon production for stocks that rear within the stream. In non-glacial streams, summer flows are maintained by precipitation, connectivity to wetland discharges, and groundwater inputs. Reductions in these inputs will reduce that amount of habitat; hence the number of salmon dependent on adequate summer flows.

In the fall, juvenile salmon that remain in freshwater begin to move out of the mainstems, and again, off-channel habitat becomes important. During the winter, coho, steelhead, bull trout, and remaining chinook parr require habitat to sustain their growth and protect them from predators and winter flows. Wetlands, stream habitat protected from the effects of high flows, and pools with overhead are important habitat components during this time.

Except for bull trout and resident steelhead, juvenile parr convert to smolts as they migrate downstream towards the estuary. Again, flows are critical, and food and shelter are necessary. The natural flow regime in each river is unique, and has shaped the population's characteristics through adaptation over the last 10,000 years. Because of the close inter-relationship between a salmon stock and its stream, survival of the stock depends heavily on natural flow patterns.

The estuary provides an ideal area for rapid growth, and some salmon species are heavily dependent on estuaries, particularly chinook, chum, and to a lesser extent, pink salmon. Estuaries contain new food sources to support the rapid growth of salmon smolts, but adequate natural habitat must exist to support the detritus-based food web, such as eelgrass beds, mudflats, and salt marshes. Also, the processes that contribute nutrients and woody debris to these environments must be maintained to provide cover from predators and to sustain the food web. Common disruptions to these habitats include dikes, bulkheads, dredging and filling activities, pollution, and alteration of downstream components such as lack of woody debris and sediment transport.

All salmonid species need adequate flow and water quality, spawning riffles and pools, a functional riparian zone, and upland conditions that favor stability, but some of these specific needs vary by species, such as preferred spawning areas and gravel. Although some overlap occurs, different salmon species within a river are often staggered in their use of a particular type of habitat. Some are staggered in time, and others are separated by distance.

Chum and pink salmon use the streams the least amount of time. Washington adult pink salmon typically begin to enter the rivers in August and spawn in September and October, although Dungeness summer pinks enter and spawn a month earlier (WDFW and WWTIT 1994). During these times, low flows and associated high temperatures and low dissolved oxygen can be problems. Other disrupted habitat components, such as less frequent and shallow pools from sediment inputs and lack of canopy from an altered riparian zone or widened river channel, can worsen these flow and water quality problems because there are fewer refuges for the adults to hold prior to spawning. Pink salmon fry emerge from their gravel nests around March and migrate downstream to the estuary within a month. After a limited rearing time in the estuary, pink salmon migrate to the ocean for a little over a year, until the next spawning cycle. Most pink salmon stocks in Washington return to the rivers only in odd years. The exception is the Snohomish Basin, which supports both even- and odd-year pink salmon stocks.

In Washington, adult chum salmon (3-5 years old) have three major run types. Summer chum adults enter the rivers in August and September, and spawn in September and October. Fall chum adults enter the rivers in late October through November, and spawn in November and December. Winter chum adults enter from December through January and spawn from January through February. Chum salmon fry emerge from the nests in March and April, and quickly outmigrate to the estuary for rearing. In the estuary, juvenile chum follow prey availability. In Hood Canal, juveniles that arrive in the estuary in February and March migrate rapidly offshore. This migration rate decreases in May and June as levels of zooplankton increase. Later as the food supply dwindles, chum move offshore and switch diets (Simenstad and Salo 1982). Both chum and pink salmon have similar habitat needs such as unimpeded access to spawning habitat, a stable incubation environment, favorable downstream migration conditions (adequate flows in the spring), and because they rely heavily on the estuary for growth, good estuary habitat is essential.

Chinook salmon have three major run types in Washington State. Spring chinook are generally in their natal rivers throughout the calendar year. Adults begin river entry as early as February in the Chehalis, but in Puget Sound, entry doesn’t begin until April or May. Spring chinook spawn from July through September and typically spawn in the headwater areas where higher gradient habitat exists. Incubation continues throughout the autumn and winter, and generally requires more time for the eggs to develop into fry because of the colder temperatures in the headwater areas. Fry begin to leave the gravel nests in February through early March. After a short rearing period in the shallow side margins and sloughs, all Puget Sound and coastal spring chinook stocks have juveniles that begin to leave the rivers to the estuary throughout spring and into summer (August).

Within a given Puget Sound stock, it is not uncommon for other chinook juveniles to remain in the river for another year before leaving as yearlings, so that a wide variety of outmigration strategies are used by these stocks. The juveniles of spring chinook salmon stocks in the Columbia Basin exhibit some distinct juvenile life history characteristics. Generally, these stocks remain in the basin for a full year. However, some stocks migrate downstream from their natal tributaries in the fall and early winter into larger rivers, including the Columbia River, where they are believed to over-winter prior to outmigration the next spring as yearling smolts.

Adult summer chinook begin river entry as early as June in the Columbia, but not until August in Puget Sound. They generally spawn in September and/or October. Fall chinook stocks range in spawn timing from late September through December. All Washington summer and fall chinook stocks have juveniles that incubate in the gravel until January through early March, and outmigration downstream to the estuaries occurs over a broad time period (January through August). A few of these stocks have a component of juveniles that remain in freshwater for a full year after emerging from the gravel nests.

While some emerging chinook salmon fry outmigrate quickly, most inhabit the shallow side margins and side sloughs for up to two months. Then, some gradually move into the faster water areas of the stream to rear, while others outmigrate to the estuary. Most summer and fall chinook outmigrate within their first year of life, but a few stocks (Snohomish summer chinook, Snohomish fall chinook, upper Columbia summer chinook) have juveniles that remain in the river for an additional year, similar to many spring chinook (Marshall et al. 1995). However, those in the upper Columbia, have scale patterns that suggest that they rear in a reservoir-like environment (mainstem Columbia upstream from a dam) rather than in their natal streams and it is unknown whether this is a result of dam influence or whether it is a natural pattern.

The onset of coho salmon spawning is tied to the first significant fall freshet. They typically enter freshwater from September to early December, but has been observed as early as late July and as late as mid-January (WDF et al. 1993). They often mill near the river mouths or in lower river pools until freshets occur. Spawning usually occurs between November and early February, but is sometimes as early as mid-October and can extend into March. Spawning typically occurs in tributaries and sedimentation in these tributaries can be a problem, suffocating eggs. As chinook salmon fry exit the shallow low-velocity rearing areas, coho fry enter the same areas for the same purpose. As they grow, juveniles move into faster water and disperse into tributaries and areas which adults cannot access (Neave 1949). Pool habitat is important not only for returning adults, but for all stages of juvenile development. Preferred pool habitat includes deep pools with riparian cover and woody debris.

All coho juveniles remain in the river for a full year after leaving the gravel nests, but during the summer after early rearing, low flows can lead to problems such as a physical reduction of available habitat, increased stranding, decreased dissolved oxygen, increased temperature, and increased predation. Juvenile coho are highly territorial and can occupy the same area for a long period of time (Hoar 1958). The abundance of coho can be limited by the number of suitable territories available (Larkin 1977). Streams with more structure (logs, undercut banks, etc.) support more coho (Scrivener and Andersen 1982), not only because they provide more territories (useable habitat), but they also provide more food and cover. There is a positive correlation between their primary diet of insect material in stomachs and the extent the stream was overgrown with vegetation (Chapman 1965). In addition, the leaf litter in the fall contributes to aquatic insect production (Meehan et al. 1977).

In the autumn as the temperatures decrease, juvenile coho move into deeper pools, hide under logs, tree roots, and undercut banks (Hartman 1965). The fall freshets redistribute them (Scarlett and Cederholm 1984), and over-wintering generally occurs in available side channels, spring-fed ponds, and other off-channel sites to avoid winter floods (Peterson 1980). The lack of side channels and small tributaries may limit coho survival (Cederholm and Scarlett 1981). As coho juveniles grow into yearlings, they become more predatory on other salmonids. Coho begin to leave the river a full year after emerging from their gravel nests with the peak outmigration occurring in early May. Coho use estuaries primarily for interim food while they adjust physiologically to saltwater.

Sockeye salmon have a wide variety of life history patterns, including landlocked populations of kokanee which never enter saltwater. Of the populations that migrate to sea, adult freshwater entry varies from spring for the Quinault stock, summer for Ozette, to summer for Columbia River stocks, and summer and fall for Puget Sound stocks. Spawning ranges from September through February, depending on the stock. After fry emerge from the gravel, most migrate to a lake for rearing, although some types of fry migrate to the sea. Lake rearing ranges from 1-3 years. In the spring after lake rearing is completed, juveniles enter the ocean where more growth occurs prior to adult return for spawning.

Coastal cutthroat have four life-history forms including anadromous (sea-run), fluvial (riverine), adfluvial (lacustrine), and resident (headwaters). Depending on specific watershed characteristics, all forms can occur within the same watershed. Coastal cutthroat exhibit the broadest range of occupied habitats, migratory behavior, age at first spawning, and frequency of repeat spawning of any salmonids (Johnson 1981; Northcote 1997 as cited in WDFW 2000).

Anadromous coastal cutthroat typically spawn in small streams. In Washington, most anadromous coastal cutthroat spawn from January through April, with the peak of spawning in February. Spawning occurs in riffles where the water depth is about 15 to 45 cm, in areas of low gradient and low flow (Johnson 1981, Trotter 1989 as cited in WDFW 2000). Adults surviving after spawning tend to return to salt water in late March and early April (Trotter 1989 as cited in WDFW 2000) Survival after spawning and the number of times adults return to spawn during its lifetime is variable, but individuals may return to spawn as often as 6 times (Johnson et al. 1999).

Eggs hatch within six to seven weeks, and alevins remain in gravel for about two weeks after hatching (Trotter 1989). Fry emerge from spawning gravels from March through June (Johnson et al. 1999). Newly emerged fry move quickly to low-velocity water at stream margins and backwaters and remain there through the summer to feed (Trotter 1989). Most juveniles remain in freshwater for two to four years before smolting and migrating to salt water, though the range extends from one to six years (Giger 1972, Lowery 1975 as cited in WDFW 2000). Emigration occurs in spring.

WATERSHED CONDITION

WRIA 28 General Description

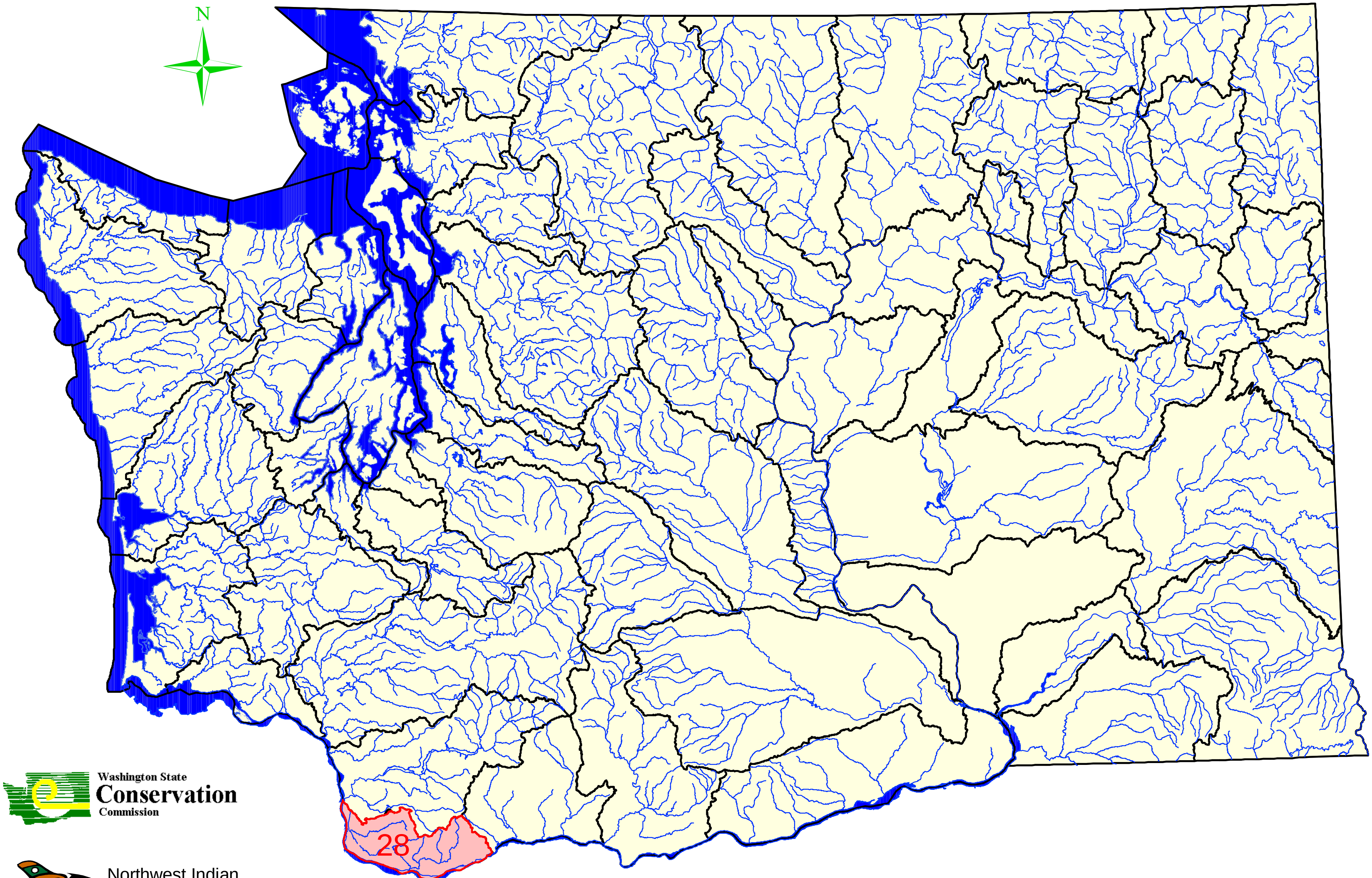
Water Resource Inventory Area (WRIA) 28 is located in Southwest Washington, with boundaries that extend to the western margins of the Wind River to the east, the Columbia River to the south, and the East Fork Lewis River to the north (see Figure 1or Location Map A-1 in Appendix A). The inventory area includes the southern and eastern portions of Clark County and southwestern Skamania County. Approximately 75% of the WRIA is in Clark County and 25% is in Skamania County. For purposes of this report WRIA 28 was divided into three major subbasins: the Lake River Subbasin, the Washougal River Subbasin, and the Bonneville Tributaries Subbasin. These drainages cover approximately 316,365 acres or 494 square miles and enter the Columbia River between river mile (RM) 87.6, at Lake River, and RM 142.3 near Bonneville Dam (Wildrich et al. 1998)

Lake River Subbasin includes all streams that flow into Lake River or Vancouver Lake. Salmon Creek, Burnt Bridge Creek, and Whipple Creek form the major watersheds in the subbasin. Salmon Creek is the largest (91 square miles and approximately 26 miles long) and most productive stream within the Lake River Subbasin. Most streams within the subbasin have been substantially altered by urban and rural residential development, agriculture, and forestry (Harvester and Wille 1989). Winter steelhead, coho, and coastal cutthroat trout still spawn and rear in many of the streams within the subbasin.

The Washougal River is the largest and most productive river basin in WRIA 28. It is approximately 36 miles long and has a drainage area of about 240 square miles (WDF 1951). A number of major tributaries to the Washougal provide productive habitat for 3 runs of salmon, summer and winter steelhead, and coastal cutthroat trout. The Washougal River originates in the Cascade foothills in Skamania County and flows southwesterly through the Willamette-Puget Trough and then through the Columbia River Valley for two miles before entering the Columbia River at RM 121 near the City of Camas (Caldwell et al. 1999).

The Bonneville Subbasin contains a number of short tributaries that drain into the Columbia River between RM 121 and 142.3 including: Gibbons, Lawton, Good Bear, Duncan, Woodward, Hardy, Hamilton, and Greenleaf Creeks. The gradient increases quickly in most of the streams within the Columbia River Gorge as they leave the Columbia River floodplain. A number of the Bonneville Subbasin tributaries fall within the boundaries of the Columbia River Gorge National Scenic Area. Springs and seeps within the lower reaches of various streams in the subbasin provide critical spawning sites for “threatened” stocks of Columbia River chum. Steelhead, coho, and coastal cutthroat trout also utilize the streams.

Figure 1: Location of WRIA 28



Washington State
Conservation
Commission

Northwest Indian
Fisheries Commission

Location of WRIA 28 outlined in Red

Land Ownership:

Land ownership within WRIA 28 is a mixture of private, state, federal, and local government (see Public Lands Map A-2 in Appendix A). Private land ownership accounts for over 74% of the total acreage in WRIA 28 (see Table 1). Federal lands in WRIA 28 include several national wildlife refuges that border the Columbia River including: the Ridgefield National Wildlife Refuge, Steigerwald National Wildlife Refuge, Pierce Ranch National Wildlife Refuge, and Franz Lake National Wildlife Refuge. Also, small portions of the Gifford Pinchot National Forest extend into the upper reaches of the North Fork and mainstem Washougal Rivers (see Map A-2).

The Washington Department of Fish and Wildlife and Clark County manage large acreages within the Columbia River lowlands, surrounding and to the north of Vancouver Lake. These properties are managed to provide fish and wildlife habitat, open space, and recreational opportunities for people within the area (Clark County 1994). Clark County also owns a substantial amount of acreage along the lower reaches of Salmon Creek that is managed for both open space values and active recreation.

The majority of public lands in WRIA 28 are held by Washington State Department of Natural Resources for commercial timber production (see Table 1 from Lunnetta et al. 1997). Most of the state owned land is located in the upper Washougal River Subbasin. Industrial timber companies also own and manage large properties in the upper Washougal River watershed. Washington State Parks owns and manages a large parcel of land at Beacon Rock State Park, as well as Reed Island in the Columbia River (see Map A-2).

Major urban areas within WRIA 28 include the City of Vancouver (the largest urban area), Battle Ground, Camas, Orchards and Washougal. Portions of the inventory area have experienced rapid population growth and industrial development over the last 40 years. For example, Clark County has experienced a threefold increase in population size within the un-incorporated areas since 1960 (Hutton 1994).

Table 1: WRIA 28 Land Ownership (acres and percentage of total)

Ownership Type	**Private**	**USFS**	**USFWS**	**NPS**	**County**	**City**	**State**	**DOD**	**Sum**
Acres	234,181	15,624	3,494	65	1,184	864	57,602	3,083	316,094
Percentage of total acres	74.11	4.94	1.11	0.02	0.37	0.27	18.20	0.98	100%

Data from EPA summary statistics compiled in 1995.

Land Uses:

Agriculture is the dominant land use in the western and central parts of WRIA 28. The southwest portion of WRIA 28 is predominately urbanized, especially on the alluvial terraces and flood plain of the Columbia River. The City of Vancouver is the largest of urban center in WRIA 28. Silvaculture dominates land use on steeper ground to the east in the foothills of the Cascade Range (Wildrick et al. 1998). Manufacturing, especially in the technology sector, has increased in the urban centers of Camas and Vancouver following the rapid population growth observed since the 1960's (Wildrick et al. 1998). Industrial and commercial development extends along the Columbia River from Vancouver to the flushing channel to Vancouver Lake and along the Camas Slough near the mouth of the Washougal River. Rapid urban and rural residential development has occurred along most of the streams within WRIA 28; especially along streams within the Lake River Subbasin, the lower 20 miles of the Washougal River, and the Little Washougal watershed (TAG).

National wildlife refuges, state wildlife areas, and Clark County open space properties occupy large acreages of land along the Columbia River and around Vancouver Lake in WRIA 28. The geographical setting on the Columbia River floodplain has provided a unique opportunity to restore and enhance wetland areas. Historically, a prolific wetland area dominated the landscape at the convergence of the Columbia and Willamette Rivers. However, there has been a loss of these wetland habitats over the past 40 years due to urban, agricultural, and industrial development.

Land development and uses are limited in the southeastern portions of WRIA 28 due to regulatory limits on development within the Columbia River Gorge National Scenic Area (CRGNSA)(Public Law 99-663, the Columbia River George National Scenic Area Act). Yet, development is occurring within the urban centers of the Columbia Gorge and railroad and highway transportation corridors cut across all streams within the Bonneville Tributaries Subbasin near their confluence with the Columbia River.

Portions of the upper Washougal River and Bonneville Tributaries Subbasins are located within the USFS Gifford Pinchot National Forest. Many visitors visit this forest every year for a variety of recreational activities. State and private commercial forest lands cover a substantial amount of area in the upper Washougal River Subbasin.

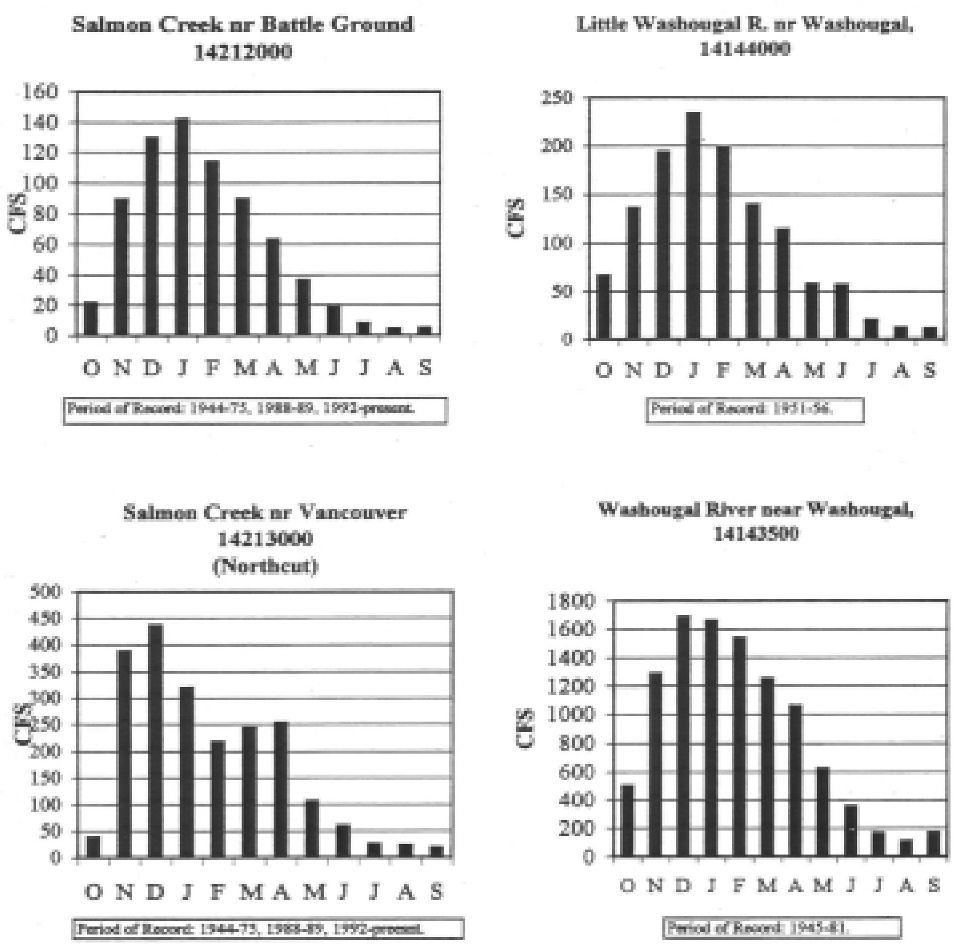
Climate:

The climate of Southwestern Washington is strongly influenced by its physical geography and position between the coastal Willapa Range to the west and the Cascade Range to the east. The Columbia River to the south and west, and Pacific Ocean (70 miles to the west) help moderate temperatures year-round. Maritime influences result in mild, cool, wet winters and moderately dry, warm summers. Orographic effects in the region are pronounced, with average annual precipitation varying from 41.3 inches (on average from 1961-1990) in Vancouver, situated in the Puget-Trough lowlands, to over 110 inches per year in the upper Cascade Range (Wildrick et al. 1998). Precipitation provides most of the surface and groundwater in WRIA 28 (Wildrick et al. 1998; WDF 1990). Over the period of record, annual precipitation has varied by a factor of about two and one-half times (24-64 inches) in WRIA 28. The average annual temperature in Clark County is 50° F, ranges from winter lows rarely below 32° F to summer highs rarely exceeding 80° F (Wildrich et al. 1998).

Hydrology:

Since there are no permanent snowpacks, reservoirs, or other major impoundments, streamflow is the direct result of rainfall and groundwater runoff (Wildrich et al. 1998; WDF 1990). Figure 2 illustrates mean monthly streamflows from long-term records for the Washougal River and Salmon Creek. Ground-water storage is recharged mainly by precipitation that percolates down to the water table, or by infiltration from streams or other water bodies. Barring long-term climatic change, ground water storage usually stays within a narrow range, and the average annual recharge rate may be assumed to be equivalent to the average discharge of ground water to streams, springs, or other surface water bodies (Wildrich et al. 1998). According to Wildrich et a. (1998) we can only estimate the historic rates of natural streamflow in WRIA 28 because streamflows were not measured prior to land clearing, cultivation, and development of water supplies.

Figure 2: Mean monthly streamflows in the Washougal River and Salmon Creek



From Wildrick et al. 1998

In a watershed assessment of WRIA 28, Wildrich et al. (1998) provided an excellent description of the soil-water balance for the area. According to Wildrich et al. (1998) precipitation is more abundant during the fall and winter, and as soils become saturated, excess soil moisture tends to percolate beyond the reach of plant roots and recharges ground water. In some areas, water logging of soils results in overland flows of excess water to streams. During spring and summer, ground-water recharge practically ceases because the actual evapotranspiration rate (AET) usually exceeds the rate of precipitation. This annual cycle is reflected in low streamflows during the summer and fall and higher flows during winter and spring. Soil-water balance estimates were developed for both Salmon Creek and the Vancouver area. Both of the estimated water balances indicate that, under normal conditions, very little ground-water recharge occurs from June through September because a soil-water deficit develops, leaving little water to percolate down to the water table. During this period, heads decline as ground water drains to streams. These seasonal imbalances in recharge lead to large seasonal swings in streamflow and ground water storage (Wildrich et al. 1998).

Geology:

Wildrich et al. (1998) also provides the best description of the geology of WRIA 28. According to Wildrich et al. (1998), "Swanston et al. (1993) completed the most recent geologic and hydrogeologic mapping of WRIA 28. They studied the much larger Portland Basin, a northwest-southeast trending structural basin about 20 miles wide and 45 miles long, filled with mostly continental sediments of the late Miocene, Pliocene, Pleistocene age. In this basin they mapped eight hydrogeologic units, grouped into three major subbasins. From youngest to oldest, these subbasins are the (1) unconsolidated sedimentary aquifer, (2) Troutdale gravel aquifer (sedimentary rocks, and (3) older rocks (including marine sediments, basalt, volcanic breccia, and volcaniclastic sediment).

The older rocks that underlie the Columbia River floodplain and terraces at varying depths also form the western foothills of the Cascade Range. To the north and east of Washougal, the older rocks belong to several geologic formations, including the Skamania Volcanics and the Columbia River basalt group… West of Washougal, a thick sequence of sediments, deposited during the Miocene through the Pleistocene epochs, fills a structural basin formed during faulting and downwarping of the older rocks. These sediments belong to several geologic formations, including the Sandy River mudstone and the Troutdale Formation, both of Eocene age.

During the late Pleistocene time, large quantities of sediments were deposited over the Troutdale Formation. These sediments consist of basaltic boulders and cobbles with a gravel and sand matrix and were deposited throughout most of the study area north and east of Washougal during repeated catastrophic floods of the Columbia River. The flood deposits generally are coarsest near the present channel of the Columbia River, then grade into finer-grained facies of stratified san, silt, and clay to the Northwest (Swanton et al. 1993).

Holocene age alluvium occurs along the floodplains of the Columbia River and its major tributaries. Columbia River alluvium consists largely of sand and silt, while alluvium of its major tributaries consists chiefly of cobbles and gravel."

Topography:

The topography within WRIA 28 varies from approximately 3,000-feet mean sea level (MSL) in the Cascade Range to approximately 10 feet MSL within the Columbia River floodplain. The Columbia River alluvial floodplain follows the Columbia River as it flows west to northwest along the southern border of WRIA 28. Several lowland lakes remain in WRIA 28 despite earlier land use practices that drained most of the lakes adjacent to the Columbia River floodplain. Lacamas Lake is the largest upland lake at 347 acres, followed by Battleground Lake at 28 acres and Dead Lake at 16 acres (Wildrick et al. 1998).

Vegetation Cover and Composition:

The forest series or zones in WRIA 28 are typical of those found in the southern Cascades of Washington State. These forest zones are based on the climax tree species of the four major plant communities within the basin (western hemlock, Pacific silver fir, mountain hemlock, and subalpine fir). Above 3,500 feet, forests are generally Pacific silver fir with Douglas fir, western hemlock, mountain hemlock, and lodgepole pine as common associates. Understory is primarily huckleberry, fool's huckleberry, and salal. Below 3,500 feet, climax species are western hemlock, Douglas fir, and western red cedar. Understory species include vine maple, huckleberry, salal, sword fern, and devil's club. Hardwood species (alder, cottonwood, maple, and willow) are concentrated in riparian corridors along larger streams and rivers (WDF 1990).

Historically, fire was the strongest natural disturbance influencing vegetation structure and composition within these different plant communities (USFS 1995). However, the eruption of Mount St. Helens has shown the potential influence that volcanism can also exert on vegetation composition and structure within a watershed. Logging, and in areas grazing, have had substantial impacts on vegetation structure and composition and riparian areas throughout WRIA 28 (WDF 1990).

The largest fire, the Yacolt Burn, occurred in 1902 and covered an estimated 238,900 acres of state, private, and federal lands extending from the foothills of the Cascades. Fires repeatedly burned over the portions of the same area, including the Rock Creek Fire of 1927 (48,000 acres), and the Dole Fire of 1929 (227,500 acres). Some areas have burned over five times, with the last major fires occurring in 1952 (USFS 1995; Parson date unknown). Besides destroying most if not all of the vegetation within the burned areas, these fires were especially hot. Portions of the higher peaks and ridges burned so hot that shrub/forb seral stages still predominate (USFS 1995).

Sediment loading, high stream temperatures, insufficient canopy cover, large peak flows, and soil productivity were probably at their worst soon after the large fires. The major flood events occurring in 1931 and 1934 were probably associated with rain-on-snow precipitation events that coincided with major fires (USFS 1995). Natural processes are slowly healing the landscape, and many of the associated problems have decreased in severity. However, the number of pieces of large woody debris per mile of stream, and the vegetation structure, composition, and age-class distribution remain well outside of historic conditions today, and are projected to remain outside historic conditions well into the future.

The Washington Department of Natural Resources derived vegetation cover for WRIAs in Western Washington, including WRIA 28, using 1988 Landsat 5 TM data (PMR 1993) and updated with 1991 and 1993 TM data (see Lunetta et al. 1997 for additional details). Forest cover was broadly categorized into four classes based on forest type and age class (see Table 2). The non-forest land cover and most surface water features were then overlaid on the forest-cover classification to discriminate non-forest lands, such as agriculture and urban areas from forestlands (PMR 1993).

Table 2: **Land Cover Categories Derived from Landsat 5 TM data (PMR 1993 and WDNR 1994).**

Land Cover Category	**Description**
Class 1: Late Seral Stage	Coniferous crown cover >70%. More than 10% crown cover in trees =21 inches in diameter breast height (dbh)
Class 2: Mid-Seral Stage	Coniferous crown cover >70%. Less than 10% crown cover in trees =21inches dbh
Class 3: Early Seral Stage	Coniferous crown cover =10% to 70%. Less than 75% of total crown cover in hardwood tree/scrub cover.
Class 4: Other Land in Forested Areas	Less than 10% coniferous crown cover (can contain hardwood tree/scrub cover; cleared forest land; etc.
Class 5: Surface Water	Lakes, large rivers, and other water bodies
Class 15: Non-Forest Lands	Urban, agriculture, rangeland, barren, and glaciers

Adapted from Lunetta et al. 1997.

Table 3 contains the both the number of acres in each land cover category and the percentage of the total area in each category. As you can see from Table 3, late-seral stage vegetation covers less than 1% of WRIA 28. The Yacolt Burn killed most of the remaining late-seral stage vegetation in the upper watersheds of WRIA 28 (Parsons unknown date; USFS 1995). The vegetation in WRIA 28 is still recovering from this series of extremely hot, stand-replacement fires (TAG; USFS 1995). Mid-seral stage vegetation now covers approximately 23% of the WRIA, but almost 70% of the area in WRIA 28 is covered by either the “non-forest” or “other” lands vegetation classes. Agriculture and urban development within the lowland portions of Salmon Creek, the Washougal River, the areas around Vancouver Lake and Lake River, and in the cities of Vancouver, Battle Ground, and Camas is likely responsible for most of the non-forest lands in WRIA 28. Non-forest lands cover almost 70% of the Lake River Subbasin (Lunetta et al. 1997).

Table 3: WRIA 28 Land Cover Data

WRIA 28	Late-seral	Mid-seral	Early-seral	Other lands	Water	Non-forest	Total
Acres	1,365	72,676	7,719	88,421	15,061	130,784	316,027
Percent	0.4%	23.0%	2.4%	28.0%	4.8%	41.4%	100%

Adapted from Lunetta et al. 1997.

Lake River Subbasin

The Lake River subbasin, located in Clark County, is composed of several tributaries that drain in the western portion of WRIA 28. The entire Lake River Subbasin is located within Clark County and the Vancouver Watershed Administrative Unit (WAU). Lake River is a low gradient, tidal influenced waterway, that drains into the Columbia River at RM 87.5. Lake River originates at the northern edge of Vancouver Lake, draining in a northerly direction for 11 miles before meeting Bachelor Island Slough and entering into the Columbia River 0.5 miles upstream from the confluence of the Lewis and Columbia Rivers (WRIA 27). The entire length of this low-gradient slough lies within the Columbia River floodplain. A habitat inventory of the Vancouver Lake area performed in 1986 classified Lake River as a lacustrine habitat due to channel morphology and habitat conditions (EnviroSphere 1986). Lake River flows in a northerly direction into Bachelor Slough, which enters the Columbia River 0.5 miles upstream from the Lewis River. Tidal influence is apparent in Lake River, responding to daily tidal fluctuations in the mainstem Columbia River (EPA 1978). The majority of water entering Lake River comes from Salmon Creek, Burnt Bridge Creek, Whipple Creek, and Gee Creek

Agriculture and open space land uses cover most of the Columbia River lowlands to the west of Lake River. Industrial development occurs along the Columbia River from the flushing channel to Vancouver.

Approximately 12 miles of dikes along the Columbia River and Lake River protect approximately 3,000 acres in the Vancouver Lake lowlands from flooding (Fazio 2000: personal comm.). The first diking activities ensued with the construction of the Vancouver railroad line in 1908 (Van Arsdol 1986). Diking also occurred after flooding of the Alcoa plant in 1947, and continued through the 1970’s with USACE approval for the Port of Vancouver’s proposed Vancouver Lake Dredging Plan (Van Arsdol 1986, Stevens, Thompson & Runyan, Inc. 1973). Large lacustrine environments were drained, including Shillapoo Lake in 1953 (Thomas 1992).

Vancouver Lake covers approximately 2,600 acres and drains a watershed encompassing approximately 19,000 acres. The average shoreline length is about eight miles (EPA 1978). Along the northeastern shoreline of the lake are high bluffs, which are developed for residences. The western shoreline parallels the Columbia River and is separated from the river by marshy or sandy lowlands. Mulligan Slough, on the southern edge of the lake, historically provided an overflow channel that connected the Columbia River to Vancouver Lake during high flows. Industrial development and dike construction along the Columbia River in the early 1900’s disconnected this overflow channel and altered hydraulic connections between Vancouver Lake and the Columbia River (Knutzen and Cardwell 1984; EPA 1978). A project in the early 1980s dredged Vancouver Lake and created a flushing channel that connected the lake to the Columbia River. The primary intent of the project was to improve the water quality and lake conditions for recreational purposes (EPA 1978).

The general topography of Lake River subbasin is low gradient watersheds that are typical of Clark County's flat alluvial plain. Streams within the subbasin generally flow in a westerly direction across the alluvial plain. The headwaters of Salmon Creek originate at approximately 1998 feet above mean sea level (MSL). Gradients of Lake River Subbasin tributaries are typically flat with meandering channel patterns in the lower reaches of the tributaries.

Salmon Creek is the largest tributary to the Lake River subbasin draining 91 square miles (WDF 1951). Burnt Bridge Creek joins the Lake River system at Vancouver Lake. Salmon Creek, Whipple Creek, Flume Creek and their tributaries enter Lake River between Vancouver Lake and the City of Ridgefield. Lake River drains the majority of Columbia River tributaries in western Clark County, south of the Lewis River.

Salmon Creek is the largest and most productive of tributaries in the subbasin, with a basin size of approximately 90 square miles. The headwater springs of Salmon Creek originate on Spotted Deer Mountain (606 meters) and Little Elkhorn Mountain (518 meters) and flow generally westward toward Lake River (Harvester and Wille 1989). Primary land use in the upper watershed is for timber production interspersed with smaller rural developments. Agriculture, and increasingly rural development, dominates land use in the central portion of the drainage. The lower reaches of the creek flow through a primarily urban landscape.

Burnt Bridge Creek begins in what once was a series of interconnected wetlands in eastern Clark County and flows westerly to empty into Vancouver Lake. The creek has been ditched and channelized for most of its length (Gaddis 1994). Impacts from extensive urbanization have substantially reduced the quality and quantity of habitat within the creek. Whipple Creek also flows westerly until it enters Lake River at RM 6.9. Heavy rural development and a series of passage barriers have reduced the value of this stream for anadromous fish.

Land use practices in the Columbia River flood plain, the alluvial plain, and upper higher gradient reaches have been detrimental to watershed health. Silvaculture, urbanization, and development within floodplains have had a substantial impact of salmonid habitat and water quality and quantity. Central portions of the Lake River Subbasin, which were dominated by agriculture, now serve as the urban centers of Vancouver, Orchards, Salmon Creek, Battle Ground, and Ridgefield. Silvaculture, and increasingly, rural residential development are the dominant land use along the upper reaches of this subbasin.

Salmon Creek is listed on the WDOE 303d list for fecal coliform, turbidity, and temperature excursions. Three of Salmon Creeks tributaries are also listed, two for fecal coliform and one for chlorine. Burnt Bridge Creek is listed for pH, dissolved oxygen, temperature, and fecal coliform (WDOE 2000).

Washougal Subbasin

The Washougal River drains an area of approximately 240 square miles. It is located mostly in Clark County, but includes a small portion of Skamania County. The lower two miles of the Washougal River are within the Columbia River valley. The river then enters a narrow, shallow valley until it reaches Salmon Falls (RM 14.5). From Salmon Falls to the headwaters, the river flows almost entirely within a narrow, deep canyon (WDF 1990). Major tributaries include Lacamas Creek, the Little Washougal River, Canyon Creek, the North Fork Washougal River, and Dugan Creek.

The Cities of Camas and Washougal are the largest urban centers within the Washougal subbasin. Urban and rural residential development covers a substantial portion of the lowland areas within the Subbasin. Industrial uses have impacted this area since approximately 1884 when the Crown Zellerbach pulp mill was located at the mouth of the Washougal River (Van Arsdol 1986). Agriculture is practiced on the Columbia River flood plain, but forestry uses prevail outside of the lowland areas.

The topography of the Washougal subbasin is variable. The highest elevations are located at 3,200 feet in the headwaters of Bear Creek, a first order tributary of the Washougal River. The lowest elevations are found at the mouth of the Washougal River on the Columbia River floodplain at 20 feet MSL. Topography of this area is generally rugged, limiting development to the Columbia River floodplain.

The Washougal River is a relatively low gradient tributary of the Columbia River. Slope increases at the confluence of the West Fork Washougal River at RM 14.5. Anadromous fish passage for some species was generally limited to the lower part of the river below Salmon Falls until a fishway was constructed at Salmon Falls, located at RM 14.5 (WDF 1990). Current salmon distribution continues up to RM 21 at Dougan Falls, with summer and sometimes winter steelhead moving beyond the falls into the headwaters

Rainfall and groundwater provide the available surface water in this subbasin. Discharges have averaged 873 cubic feet per second (cfs) over a 37-year period. Flows are highly variable due to topography, human induced alterations, and natural occurrences such as fire. A series of fires, termed the Yacolt burn, deforested 0.25 million acres in 1902, 1927, and 1929; reducing the hydrologic maturity of the watershed (WDF 1990; Van Arsdol 1986). As early as 1883, alterations to Lacamas River occurred by way of a tunnel connecting Lacamas Lake to the Columbia River at the present town of Camas (Van Arsdol 1986).

The Washougal River fish habitat has been degraded from the upper reaches downstream to its' mouth in Camas. The Yacolt Burn deforested large tracts of land in the upper reaches causing an increase in sediment transport, a reduction in hydrologic retention, and a general decline in habitat quality. Gravel extraction in the lower 20 miles of the river has caused a loss in suitable spawning substrate through this reach. Three dams were constructed by the Cotterell Power Company, which prevented fish passage during low flows. These dams contained fish ladders that were deemed inefficient (WDF 1990). The dams were eventually removed in 1947. Effluent from the kraft pulp mill located at the mouth of the Washougal River in Camas has been directly recognized as a contributor of fish mortality (WDF 1990; WDF 1951). Water quality remains a problem and the Washougal River is listed on the 303d list (WDOE 2000) along with several of its' tributaries.

Bonneville Tributaries Subbasin

The Bonneville tributaries (tributaries of the Columbia River from RM 121–142.3) drain the slopes of the Columbia River flood plain terraces from the City of Camas to Beacon Rock in the Columbia River Gorge National Scenic Area (CRGNSA). This subbasin contains a series of smaller tributaries that enter the Columbia River, flowing south through the Columbia River flood plain terrace to the Columbia River.

Most of the Bonneville Tributaries Subbasin is located within the Columbia River Gorge National Scenic Area (CRGNSA). An Act signed in 1986 created the Columbia River Gorge National Scenic Area to help maintain rural and scenic characteristics of the gorge, while encouraging growth and development in urban areas (Public Law 99-663, the Columbia River Gorge National Scenic Area Act). Therefore, land development and uses are limited in this area. Small patches of land in this sub-basin are in federal ownership under the USFS Gifford Pinchot National Forest.

Bonneville Tributaries Subbasin is characterized by the geomorphology of the Columbia River Gorge. Proceeding upriver from Gibbons Creek, the Columbia soon leaves the broad floodplains that characterize the lower river and enters the Columbia River Gorge with steep slopes flanking the river. In the Gorge, tributaries of the Columbia River have only a small amount of low gradient spawning habitat in the lower reaches before the gradient becomes to steep for fish to traverse. For example, gradient within the lower 3 miles of Duncan Creek averages approximately 3% to 4%. For the next 0.7 mile channel gradient averages around 28%. Good Bear Creek has only 0.3 miles of low gradient (3% slope) channel before it climbs to 11% slope over the next 0.3 miles (USFS stream survey data from 1994 and 1995).

Woodward, Hardy, Hamilton, Lawton, and Greenleaf Creeks are the largest drainages of the Bonneville subbasin. Elevation of the headwaters ranges from 2000-3000 feet. Hamilton Creek has the longest channel length measuring over 8 miles. Several unnamed tributaries flow for less than a mile before entering the Columbia River.

Lower gradient reaches of these tributaries on the Columbia River flood plain serve as the primary spawning and rearing habitat for anadromous fish. Habitat alterations occurred in these lower reaches through the development of transportation systems along the Columbia River Gorge. The construction of the railroad has created pinch points in the lower reaches. State route 14 cuts across all of the creeks in this subbasin. The operation of Bonneville Dam, on the eastern edge of the subbasin, has significantly altered the natural flow regime in the subbasin as well as in all of WRIA 28, and the construction of the dam reduced connections to historic overflow channels in Greenleaf and Hamilton Creeks.

DISTRIBUTION AND CONDITION OF STOCKS

The distribution of winter and summer steelhead, fall chinook salmon, coho salmon, and chum salmon was mapped within WRIA 28 at a 1:24,000 scale for this Habitat Limiting Factors Analysis. Maps for each of these anadromous species were developed using existing literature and databases, such as the Washington State Salmon and Steelhead Stock Inventory (SASSI: WDF et al. 1993), Washington State Salmonid Stock Inventory Coastal Cutthroat Trout (Blakely et al. 2000), the draft Lower Columbia Steelhead Conservation Initiative Draft (LCSCI 1998), Streamnet, and Washington Department of Fish and Wildlife (WDFW) stream and spawning surveys (see Maps A-3 through A-7 in Appendix A). Members of the WRIA 28 Technical Advisory Group (TAG) added considerably to this existing database with their professional knowledge of fish distribution within WRIA 28 stream systems.

For each species, known, presumed, and potential distribution was mapped (see Appendix C: Fish Distribution Definitions). Table 4: WRIA 28 Fish Distribution and Barriers, represents a compilation of all the fish distribution data that was collected for each stream as well as the number of miles of stream affected by physical barriers. Table 5 displays the same information, but it is summarized by subbasin.

Table 4: WRIA 28 Fish Distribution and Barriers

	Species Present					**Miles of Use**			**Physical Barriers (miles)**		
Stream Name	chum	coho	fc	ss	ws	kn.	pres	pot	dam	culvert	other
Lake River Subbasin											
Lake River		X			X						
Whipple Creek		X			X		1.5	3.0		1.5	
Packard Creek		X			X			0.7		0.7	
Salmon Creek		X			X	24.4					
Mill Creek		X			X	6.4					
Curtain Creek		X			X	1.0	1.9				
Woodin/Weaver Cr.		X			X	3.2	2.2				
Morgan Creek		X			X	3.0	1.0				
Mud Creek					X	0.7					
Baker Creek		X			X	0.6		1.0			1.0
Rock Creek		X			X	3.6					
Unnamed		X			X		2.0				
Burnt Bridge Cr.		X			X		16.3				
Washougal River Subbasin											
Washougal River	X	X	X	X	X	32.0*					
Lacamas Creek	X	X	X		X		0.9				
Little Washougal R.		X	X	X	X	7.6*					
EF Little Washougal		X		X	X	3.3*					
Jackson Creek		X		X	X	0.7					

	Species Present					Miles of Use			Physical Barriers (miles)		
Stream Name	chum	coho	fc	ss	ws	kn.	pres	pot	dam	culvert	other
Boulder Creek		X		X	X	2.8*					
Jones Creek		X		X	X	2.4*					
Larson Creek		X			X			0.4		0.4	
Cougar Creek				X		2.3*					
Winkler Creek				X	X	0.6	0.8			0.8	
NF Washougal R.		X		X	X	8.5*	2.2*				
Wild Boy Creek		X		X	X	1.8*		1.7*	1.7		
Texas Creek		X		X	X	3.5*					
Hagen Creek				X		0.7*					
Dougan Creek				X	X	1.1*	2.7*				
Stebbins Creek				X		2.8*	1.3*				
Timber Creek				X		1.4*					
Silver Creek				X		1.0*					
Prospector Creek				X		0.2*					
Meander Creek				X		0.8*					
Grouse Creek				X			0.5*				
Lookout Creek				X		0.2*					
Bear Creek				X		0.6*					
Bonneville Tributaries Subbasin											
Gibbons Creek		X			X	4.0		1.4		1.4	
Campen Creek		X			X	1.4		1.0		1.0	
Wooding Creek					X		1.4				
Third Tributary		X			X	0.8					
Lawton Creek	X	X			X	1.6					
Archer Creek	X	X			X	0.5					
Goodbear Creek	X	X			X	0.5					
Duncan Creek	X	X			X	1.9			1.1		
Woodward Creek		X			X	1.7					
Hardy Creek	X	X	X		X	1.4		0.9		0.9	
Hamilton Creek	X	X	X		X	4.8					
Greenleaf Creek		X			X	2.5					
Indian Mary Creek		X			X	2.3					

fc = Fall Chinook; ws = Winter Steelhead; ss = Summer Steelhead
kn = Known Presence; pres = Presumed Presence; pot. = Potential Presence
Winter Steelhead Distribution was used to denote miles of Known, Presumed, and Potential habitat except where Summer steelhead distribution was greater.

Table 5: WRIA 28 Fish Distribution and Barriers by Subbasin

Subbasin	Species Present					Miles of Use			Physical Barriers (miles)		
	chum	coho	fc	ss	ws	kn.	pres	pot	dam	culvert	other
Lake River Subbasin		X			X	42.9	24.9	4.8		2.2	1.0
Washougal River Subbasin	X	X	X	X	X	74.3	8.4	1.7	1.7	1.2	
BonnevilleTributaries Subbasin	X	X	X		X	23.3	1.4	3.4	1.1	3.3	

fc = Fall Chinook; ws = Winter Steelhead; ss = Summer Steelhead
Kn = Known Presence; Pres = Presumed Presence; Pot. = Potential Presence
Winter Steelhead Distribution was used to denote miles of Known, Presumed, and Potential habitat except where Summer steelhead distribution was greater.

Fall Chinook (Oncorhynchus tshawytscha)

Fall chinook distribution within WRIA 28 is now limited to the Washougal River watershed and the lower reaches of Hardy and Hamilton Creeks (see map A-6 in Appendix A). SASSI (WDF et al. 1993) only recognizes the Washougal River fall chinook stock. However, Bryant (1949) reported that a survey party in 1936 found 19 chinook salmon spawning within Salmon Creek, and WDF (1951) estimated fall chinook escapement within Salmon Creek at 100 fish in 1950, all of which spawned within the lower 5 miles.

Bryant (1949) compiled information on stream surveys conducted in the late 1930's. These surveys provided estimates of the amount of suitable spawning habitat and the number of spawning salmon pairs that this habitat could support. According to Bryant there was spawning area for approximately 5,000 pairs of salmon (all species) in the Washougal River below Salmon Falls (RM 14.5). In 1951, WDF estimated escapement of fall chinook within the Washougal River at 3,000 fish.

Today, fall chinook within the Lower Columbia River Evolutionary Significant Unit (ESU) are federally listed as "threatened" under the Endangered Species Act (NMFS 2001).

According to WDF (1990), for management purposes, there are two stocks of fall chinook below Bonneville Dam in the Columbia River; lower river hatchery (LRH), lower river wild (LRW). Fall chinook returning to the Washougal are lower river hatchery fish. Native fall chinook have been reported in the Washougal (WDF 1951), but a distinct stock probably no longer exists (WDF 1990; WDF et al. 1993). Natural spawning does occur, but these fish are identified as hatchery strays (WDF 1990).

Brood stock for the Washougal Hatchery was usually obtained from local returning stocks; however, transfers of other stocks into the system were a common practice (WDF 1990).

The Washougal River fall chinook stock was designated on the basis of spawning time and geographic distribution. Washougal River fall chinook spawn in the area from Salmon Falls (RM 14.5) downstream approximately 4.0 miles (WDF et al. 1993; WDF 1973; WDF 1951). Natural escapement is estimated using spawning ground counts within selected index areas. Natural spawn escapements from 1967-1991 averaged 1,832 with a low return of 70 in 1969 and a peak return of 4,578 in 1989 (WDF et al. 1993). Since 1971, the annual natural escapement has averaged 2,157 fish. SASSI (WDF et al. 1993) listed the Washougal River fall chinook natural spawn stock status as healthy based on escapement trend (see Table 6).

Natural spawning occurs in the Washougal River slightly later (October to November) than other lower Columbia River tule fall chinook stocks. The Washougal River fall chinook natural spawners are a mixed stock of composite production (WDF et al. 1993).

Table 6: WRIA 28 Fall Chinook SASSI Stock and ESA Status

Stock	Screening Criteria	SASSI Stock Status (1993)	Estimated SaSI Status (2000)	Status (ESA Listing)
Washougal Fall Chinook	Escapement Trend	Healthy	Under Review	Federal "Threatened"

Adapted from WDF et al.1993.

Winter Steelhead (Oncorhyncus mykiss)

Winter steelhead are known to spawn and rear in most of the major streams within WRIA 28 (see Map A-4 in Appendix A). According to SASSI (WDF et al. 1993), winter steelhead are native to and classified as a distinct stocks based on the geographical isolation of the spawning population in Salmon Creek, the mainstem Washougal River, the North (West) Fork Washougal River, and in Hamilton Creek. All lower Columbia River steelhead stocks are characterized as native in origin and wild production type. According to the LCSCI (1998), WDFW feels that these designations are accurate even in streams where there is significant spawning by hatchery steelhead, since the peak egg-take occurs in January in lower Columbia River steelhead hatcheries and peak spawning for wild fish is in April. Similar to other wild winter steelhead stocks in the lower Columbia River area, run timing for the WRIA 28 stocks is generally from December through April and spawn-timing is generally from early March to late May or early June (WDF et al. 1993).

Steelhead within the Lower Columbia River Evolutionary Significant Unit (ESU) are federally listed as "threatened" under the Endangered Species Act (NMFS 2001).

<u>Lake River Subbasin:</u>

Winter steelhead are distributed throughout many of the streams within the Lake River Subbasin (see Map A-4). Other than noting presence, historical data on run size and distribution is lacking. Bryant (1949) noted that steelhead were reported to use Salmon Creek. Both SASSI (WDF et al. 1993) and the draft Lower Columbia Steelhead

Conservation Initiative (LCSCI 1998) recognize Salmon Creek winter steelhead as a distinct stock. Salmon Creek has been planted with hatchery winter steelhead since 1957. Progeny from the Elochoman, Chambers Creek, Cowlitz, and Skamania Hatchery brood stocks have been planted. While hatchery steelhead smolts have been stocked in this and nearby streams, there is little contribution to the wild winter steelhead stock from hatchery fish spawning in the wild (WDF et al. 1993).

Both SASSI (WDF et al. 1993) and the LCSCI (1998) listed stock status in Salmon Creek as “depressed” based on chronically low spawner escapement in the watershed and a reduction in sport harvest (see Table 7). The spawner escapement goal for Salmon Creek winter steelhead was listed as 400 wild winter steelhead in both SASSI and LCSCI (1998)(see Table 8). LCSCI (1998) estimated that fewer than 100 wild winter steelhead return to spawn in Salmon Creek.

Table 7: WRIA 28 Winter Steelhead Stock Status

Winter Steelhead Stock	Screening Criteria	SASSI Stock Status (1993)	LCSCI Stock Status (1997)	Status (ESA Listing)
Salmon Creek	Chronically low	Depressed	Depressed	Federal “Threatened”
Mainstem Washougal	Short-term severe decline	Unknown	Depressed	Federal “Threatened”
North Fork Washougal	----	Unknown	Not recognized	Federal “Threatened”
Hamilton Creek	Unknown	Unknown	Unknown	Federal “Threatened”

Adapted from WDF et al.1993 and LCSCI 1998.

Table 8: WRIA 28 Winter Steelhead Escapement Estimates

Stock	Wild Steelhead Escapement Goal	1991-1996 Average Wild Steelhead Escapement	Average % of Wild Escapement Goals	Average % of Hatchery Spawners
Salmon Creek	400	Not available	Unknown	Unknown
Mainstem Washougal	520 I	148 I	28 %	Unknown
North Fork Washougal	Not included	Not available	Unknown	Unknown
Hamilton & other tributaries	Not established	Not available	Unknown	<5%

I = Index escapement goals and counts.
Adapted from Lower Columbia Steelhead Conservation Initiative 1998.

Only one year of complete spawner surveys has been done for wild steelhead in Salmon Creek. Steelhead redd counts indicated that between 80-98 adult steelhead spawned in the Salmon Creek basin in 1988-1989 (Harvester and Wille 1989). Steelhead redds were distributed throughout the basin, from the mouth of Mill Creek to within 200 meters of Salmon Creek Falls (see Table 9). Most of the redds (97%) were found in Salmon and Morgan Creeks, and approximately 49% of the redds were located in either upper

Morgan Creek or above 182nd Avenue in Salmon Creek (Harvester and Wille 1989). Of the eleven steelhead actually observed during the survey, six were of hatchery origin.

This same study (Harvester and Wille 1989) trapped juveniles in lower Salmon Creek and estimated production within the creek of steelhead, coho, and cutthroat trout. A total of 384 steelhead juveniles were trapped between April 23rd and June 3rd of 1989; leading to an estimated total juvenile production that year of 443 steelhead. A manure spill on Mud Creek in 1987 likely killed all downstream salmon and steelhead fry, and this is the most obvious explanation for the low numbers of steelhead and cutthroat trout juveniles trapped from the 1987 brood (Harvester and Wille 1989).

Table 9: Adults Redd Counts in Salmon Creek 1988-1989

Location	Steelhead	% of total	Coho	% of total	Cutthroat	% of total
Salmon Creek	33	67	34	61	7	100
Rock Creek	1	2	13	23	0	0
Mill Creek	1	2	0	0	0	0
Morgan Creek	13	27	5	9	0	0
Curtin Creek	0	0	0	0	0	0
Erion Tributary	1	2	2	3.5	0	0
Woodin Creek	0	0	0	0	0	0
Totals	49	100	56	100	7	100

Adapted from Harvester and Wille 1989

Using the data from smolt trapping and comprehensive habitat and redd surveys Harvester and Wille (1989) estimated that steelhead populations within Salmon Creek were only 20% of their potential size (see Table 10), assuming that habitat requirements for each species were optimized. Harvester and Wille (1989) estimated that the maximum adult winter steelhead production from the creek would be 400 fish, and that potential parr production would be 14, 965 fish (see Table 11).

Data on historical distribution or run size of steelhead in other streams within the Lake River Subbasin is limited. Tag members confirmed that steelhead still spawn in Whipple and Packard Creeks. While some anecdotal information suggests that steelhead once occupied Burnt Bridge Creek (Mai and Cummings 1999), TAG members were unable to confirm steelhead presence in recent history.

Table 10: Comparison of Current and Potential Salmonid Populations in Salmon Creek

1989 Adult Estimate		Potential Adult Population	% of Potential Population
Coho	112	3,700	3.0%
Cutthroat	30	340-1,100	3.0% – 8.0%
Steelhead	80	400 (MSH*)	20.0%

MSH = Maximum Sustained Harvest
Adapted from Harvester and Wille 1989

Table 11: Potential Salmon Creek Basin Steelhead Production

Creek	Applied Parr utilization #/100m²	Potential Parr Production
Salmon Creek (Upper)	4.10	2,604
(Lower)	2.07	6,211
Mill	2.82	972
Morgan	7.17	1,883
Curtin	2.82	246
Rock	7.17	1,642
Woodin	4.10	1,407
Totals		14,965

Adapted from Harvester and Wille 1989

Washougal River Subbasin:

Winter steelhead are distributed in the mainstem Washougal, the Little Washougal and various tributaries within the Washougal Subbasin (see Map A-4 in Appendix A). Generally, Dougan Falls (RM 21.6) is considered the upstream extent of winter steelhead distribution in the mainstem Washougal (WDF 1990). Winter steelhead also move well into the headwaters of the Little Washougal watershed.

Accurate run size and harvest estimates of wild winter steelhead do not exist (WDF et al. 1990). The SASSI stock status of winter steelhead in the Washougal River was "unknown" in 1992 (WDF et al.1993). The LCSCI stock status update in 1998 listed the stock as "depressed" based on a short-term severe decline (see Table 7). The SASSI spawner escapement goal was 841 wild winter steelhead for the Washougal mainstem. This escapement goal for wild winter steelhead was lowered to 541 fish with the LCSCI update (see Table 8). Timing of adult migration most likely occurs January through May, with peak movement in March (WDF et al. 1990).

SASSI recognized a distinct stock of winter steelhead in the North Fork Washougal based on geographical isolation of the spawning population. North Fork Washougal winter steelhead spawn in the mainstem and its major tributaries.

The Skamania Hatchery is located on the lower end of the North Fork Washougal and has been stocking hatchery steelhead into the river system since 1957 (WDF et al. 1993). Approximately 110,000 hatchery winter steelhead smolts are released annually in the Washougal River. These smolts are Skamania origin steelhead, reared primarily at the Skamania Hatchery on the Washougal, but also at the Vancouver and Beaver Creek facilities (WDF et al. 1990). Interbreeding between hatchery and wild steelhead is thought to be very low because of the run timing (WDF et al. 1993).

Bonneville Tributaries Subbasin

Winter steelhead distribution occurs in most of the Bonneville Subbasin tributaries (see Map A-4 in Appendix A). Distribution is limited within these streams by both natural and artificial barriers.

Very little data exists on the historical run size of winter steelhead for the tributaries within the Bonneville Subbasin. Stream surveys from the late 1930's reported that steelhead became trapped in small pools within Duncan and Woodward Creeks during low flow periods, and that Hamilton Creek supported a small run of steelhead. Other streams within the subbasin were either not surveyed or no mention was made of steelhead (Bryant 1949). WDF (1951) also reported that steelhead spawned in Woodward, Hamilton, and Greenleaf Creeks.

Recent surveys and smolt trapping by the USFWS (Barndt et al. 2000: unpublished) on Gibbons Creek and its tributaries found steelhead juveniles only within the mainstem of Gibbons Creek below the Hans Nagel Road where a culvert blocks further upstream passage. Between April 24, 1998 and June 3, 1998, smolt outmigrant traps captured 42 steelhead juveniles, ranging in length from 81 to 199mm (mean 147mm) (fry excluded). 20% of the steelhead were one year old, 75% were age two, and 5% age three (n=20). Smolt outmigrant trapping began again on March 31, 1999 and ended June 16, 1999, and 179 steelhead smolts were measured in 1999. These ranged in size from 93mm to 249mm (mean 184.9mm), and 10% were one year old, 75% two years, and 15% three years (n=130). The trap efficiency for steelhead was estimated at 50%, and the population estimate of steelhead outmigrants was estimated at 366 +/-68.7 (s.d.=35.03)(297-435) (Barndt et al. 2000: unpublished).

SASSI lists Hamilton Creek winter steelhead as a distinct stock based on geographical isolation of the spawning population. The stock is native, with run timing similar to other lower Columbia River winter steelhead stocks (WDF et al. 1993). Hamilton Creek has received plants of hatchery winter steelhead since at least 1958 from Skamania and Beaver Creek Hatcheries. Plants have been done low in the system. These plants have not been completed every year. While hatchery steelhead smolts have been stocked in this and nearby streams, there is little contribution to the wild winter steelhead stock from hatchery fish spawning in the wild (WDF et al. 1993). The status of the stock was listed as "unknown" in both the SASSI inventory as well as in the LCSCI (1998) update. This stock is comprised of a historically small number of steelhead, but there is insufficient information to classify its stock status (WDF et al. 1993)(see Table 7). Spawning escapement is not monitored for this stock nor has an escapement goal been identified.

Summer Steelhead (Oncorhyncus mykiss)

The Washougal River and its tributaries are the only stream systems within WRIA 28 that support runs of wild summer steelhead. Stream surveyors, in July 1935, counted 539 steelhead within the Washougal River, the majority of which were unspawned fish lying in deep holes (Bryant 1949). Some 200 of these fish were found below Salmon Falls (RM 14.5) and the others above. These fish were likely mostly summer steelhead waiting until the following spring to spawn. From this 1935 stream survey data, Bryant (1949) concluded that the largest run of fish entering the Washougal River at that time was steelhead.

According to Bill McMillan (1997: letter), "the North (West) Fork Washougal once had a good return of summer steelhead, prior to the construction of the Skamania Hatchery in 1956. In the summer of 1956, 153 native steelhead were trapped at Skamania Hatchery for brood stock, whereas 260 steelhead were scuba counted in the upper mainstem Washougal. This would indicate that 37% of Washougal native summer steelhead returned to the North Fork Washougal in 1956." McMillan (1997: letter) estimated that with late summer steelhead returns included, the North Fork could provide spawning habitat for a potential population of 200-350 wild summer steelhead.

Wild summer steelhead in the mainstem Washougal River and tributaries are native and a distinct stock based on the geographical isolation of the spawning population. Similar to other wild summer steelhead stocks in the lower Columbia River area, run timing is generally from May through November and spawn-timing is generally from early March to early June. The Skamania Hatchery has been stocking hatchery steelhead into the river system since the late 1950's. There is concern about the genetic impact of potential interbreeding between wild and hatchery summer steelhead (WDF et al. 1993)(see Table 13).

Table 12: WRIA 28 Summer Steelhead Stock Status

Summer Steelhead Stock	Screening Criteria	SASSI Stock Status (1993)	LCSCI Stock Status (1997)	Status (ESA Listing)
Mainstem Washougal	Chronically low	Unknown	Depressed	Federal "Threatened"
North Fork Washougal	----	Unknown	Not recognized	Federal "Threatened"

Adapted from WDF et al.1993 and LCSCI 1998.

Table 13: WRIA 28 Summer Steelhead Escapement Estimates

Summer Steelhead Stock	Wild Steelhead Escapement Goal	1991-1996 Average Wild Steelhead Escapement	Average % of Wild Escapement Goals	Average % of Hatchery Spawners
Mainstem Washougal	576 p	57 I	<40%	1%
North Fork Washougal	295 p	Not available	Not available	87%

p= Preliminary escapement goals for the Washougal River (to be field checked)
I = Index escapement goals and counts.
Adapted from Lower Columbia Steelhead Conservation Initiative 1998.

Stock status has changed in recent years. Originally, the status of the stock was determined as "unknown" based on the 1992 SASSI Inventory (WDF et al. 1993). Limited spawner surveys and snorkel surveys of summering adults indicated low numbers of adult steelhead but not enough data was available at the time to assess the status of the stock. In a more recent study, the steelhead stock was determined to be "depressed" due to chronically low escapement measures taken between 1952 and 1997 (LCSCI 1998)(see Table 12). Steelhead within the Lower Columbia River Evolutionary

Significant Unit (ESU) are federally listed as "threatened" under the Endangered Species Act (NMFS 2001).

Coho Salmon (Oncorhynchus kisutch)

Historically, native populations of coho were present in all lower Columbia River tributaries. In the 1950's, salmon hatchery construction was expanded on the lower Columbia River tributaries and hatcheries began to trap broodstock in many areas. Over time, broodstock, eggs, and juvenile coho were transferred throughout the lower Columbia River stations. Hatchery off-station planting was commonplace throughout the lower Columbia River, resulting in a widely mixed coho stock (WDF et al. 1993). SASSI (WDF et al. 1993) recognized three distinct stocks of coho salmon in WRIA 28; Salmon Creek coho; Washougal River coho, and Bonneville Tributaries coho. All of these are considered mixed stocks of composite production.

Coho salmon within the Lower Columbia River/Southwest Washington Evolutionary Significant Unit (ESU) were recognized as a candidate species for listing under the federal Endangered Species Act in 1995 (NMFS 2001).

Coho are still distributed throughout most of the stream systems within WRIA 28 (see Map A-3 in Appendix A). In 1973, Washington Department of Fisheries considered coho salmon to be the most abundant salmon species to return to WRIA 28 (WDF 1973). Coho enter the Columbia River beginning in August and continue through December and January, with a peak in September or October. Tributary spawning extends from October through at least February with a peak in October through December (WDF et al. 1993).

<u>Lake River Coho:</u>

Known coho distribution extends throughout most of Salmon Creek and its tributaries, and into the lower reaches of Whipple and Burnt Bridge Creeks (see Map A-3). Minimal amounts of data exist on the size of historical coho escapement. Bryant (1949) stated that October 1936 stream surveys found 16 silver salmon in 14.5 miles of Salmon Creek. However, it was reported that the 1936 run was unusually small due to exceptionally low water. WDF (1951) estimated coho escapement for all WRIA 28 tributaries, other than the Washougal River, at 2,050 fish. Salmon Creek likely produced a significant proportion of this estimated coho escapement, considering that the creek and its tributaries form the second largest stream system within WRIA 28, and the watershed contains a large amount of low gradient habitat that coho prefer.

Returns of coho to the Salmon Creek watershed are not monitored. However, a 1988-1989 stream survey (Harvester and Wille 1989) determined that coho redds were distributed throughout the Salmon Creek system, from the mouth of Mill Creek to within 200 meters of Salmon Creek Falls (RM 32). Table 9 displays the survey data on adult redd counts within Salmon Creek and its tributaries. The overall abundance of coho salmon redds (56) encountered during these surveys exceeded the number of either winter steelhead redds or cutthroat trout redds. Most of the redds were discovered in Salmon

Creek (61% of the total) and in Rock Creek (23% of the total). The surveyors failed to find any redds within the surveyed reaches of Mill, Curtin, and Woodin Creeks (Harvester and Wille 1989).

Salmon Creek coho stock status is considered "depressed" based on chronically low production. Natural spawning is presumed to be quite low and subsequent juvenile production below stream potential (WDF et al. 1993). Using the data from smolt trapping and comprehensive habitat and redd surveys, Harvester and Wille (1989) estimated that salmonid populations within Salmon Creek were only 3%-5% of their potential size, assuming that habitat requirements for each species were optimized (see Table 10). Harvester and Wille (1989) estimated that the maximum adult coho production from the creek could be 3,700 fish (see Table 15).

Table 14: WRIA 28 Coho Salmon Stock Status

Coho Salmon Stock	Screening Criteria	SASSI Stock Status (1993)	Estimated SaSI Status (2000)	Status (ESA Listing)
Salmon Creek	Chronically low production	Depressed	Under Review	Candidate species
Washougal	Chronically low production	Depressed	Under Review	Candidate species
Bonneville Tributaries	Long-term decline	Depressed	Under Review	Candidate species

Adapted from WDF et al. 1993

Table 15: Potential Salmon Creek Basin Coho Salmon Production

Creek	Juveniles	Adults
Salmon	109,060	2,770
Mill	12,060	300
Morgan	9,190	230
Curtin	3,050	80
Rock	6,870	170
Woodin	5,890	150
Totals	146,120	3,700

Adapted from Harvester and Wille 1989

Washougal River Coho:

Known coho distribution extends through the mainstem Washougal River to Dougan Falls (RM 21.6), into the Little Washougal and North Fork Washougal, and into a number of smaller tributaries (see Map A-3). Minimal amounts of data exist on the historical run size of coho in the Washougal. WDF (1951) estimated that 3,000 silver salmon (coho) annually enter the Washougal River to spawn. Bryant (1949) estimated that there was spawning area for approximately 5,000 pair of salmon below Salmon Falls (RM 17.5), and another 1,000 pairs between there and Dougan Falls. Before Salmon Falls was laddered in the late 1950's, coho spawned mainly in the tributaries below the falls including the Little Washougal, Winkler Creek and the North Fork Washougal (WDF et al. 1990).

Typically, coho begin entering the Washougal River in early September and continue through November. Holding is relatively short, with spawning commencing about mid-October and continuing through November. Incubation extends from late October through January with emergence occurring in late January and early February (WDF 1990).

By the time fish surveys were first conducted in the Washougal, serious habitat damage had already occurred. Deforestation of the upper Washougal watershed due to the Yacolt Burn caused serious habitat degradation. Three small hydroelectric dams that formed low water barriers to fish migration until their removal in 1947 also degraded habitat. In 1958, the Washougal Hatchery was constructed and became a major producer of hatchery coho. Hatchery coho have been planted in the sub-basin since at least 1967. By 1973, the largest salmon run in the Washougal River was early stock hatchery coho. Minor mainstem coho spawning occurred and spawning was light to moderate in the tributaries (WDF 1973).

SASSI (WDF et al. 1993) listed the Washougal River coho stock status as "depressed" based on chronically low production (see Table 14). Natural spawning is presumed to be quite low and subsequent juvenile production is below stream potential.

<u>Bonneville Tributaries Coho</u>

Late stock coho spawn in several Bonneville Subbasin tributaries including Gibbons, Lawton, Good Bear, Woodward, Duncan, Hardy, Hamilton, and Greenleaf Creeks (TAG; WDF 1973). Combined data for Duncan, Hardy, Hamilton and Greenleaf Creeks found an average of 15 fish per mile for years when surveys occurred, starting in 1945. These surveys found a low of one fish per mile in several years and a high of 185 fish per mile in 1952 (WDF et al. 1993).

The USFWS (Barndt et al. 2000: unpublished) conducted spawning ground surveys in 1997 and 1998 on Gibbons Creek and its major tributaries. The highest peak count in 1997 was 28 coho adults on November 6^{th} when 4.32km were surveyed. The greatest number of redds counted were 72 redds on November 12^{th}; on this day the greatest distance was surveyed (7.2 km). Nineteen coho carcasses were sampled, average length of females was 606mm (n=10) and of males was 578mm (n=9). One of the female carcasses and two of the males were collected at the adult trap. During 1997, only coho were seen. Rainy weather and sediment discharge into Gibbons Creek made it difficult to survey during 1998. Only one carcass was sampled, and the highest peak count in 1998 was 2 coho on November 12^{th}. Eighteen total coho redds were counted in 1998, 17 in Gibbons Creek and 1 in Campen Creek (in the golf course).

USFWS staff also conducted smolt outmigrant trapping in 1998 and 1999 (Barndt et. a. 2000: unpublished). In 1998, smolt outmigrant trapping began on April 24^{th} and ended June 3. Overall, 558 coho were measured, ranging in size from 60mm to 146mm (mean 108mm) (fry excluded). Coho fry ranged in length from 33 to 70mm (mean 50mm). No age data was collected for coho in 1998. Smolt outmigrant trapping began again on

March 31, 1999 and ended June 16, 1999. Of the 485 coho measured in 1999; the size ranged from 87mm to 170mm (mean 118.9mm). Coho smolts were all age one (s.d.=0.25, n=16). The trap efficiency for coho was estimated at 55%. The population estimate for coho outmigrants within Gibbons Creek was 1,253 +/-127 (s.d.=63.48) (1126-1380)(Barnt et al. 2000: unpublished).

SASSI (WDF et al. 1993) listed Bonneville Tributaries coho stock status as "depressed" based on a long-term decline in escapement (see Table 14).

Chum Salmon (Oncorhynchus keta)

Numerous lower Columbia River tributaries once produced chum, including a number of streams within WRIA 28 (see A-7 in Appendix A). Chum salmon in the Columbia River were distributed historically from the mouth of the river to the Walla Walla River. The annual historic chum run size in the Columbia River has been estimated at nearly 1.4 million fish (WDFW 2000 as cited in WDFW 2001: draft). Present day annual run sizes are approximately 4,000, about three percent of the historic run size (WDFW 2001: draft)

The Washington Department of Fish and Wildlife is currently updating chum salmon stock status for Washington State and the lower Columbia River. Most of the data for chum stock distribution and condition of stocks came directly from this draft report (WDFW 2001: draft).

The size of the Columbia River chum population dropped dramatically in the 1950s (NMFS 1997). In 1951, WDF estimated chum salmon escapement within WRIA 28 at approximately 5,000 fish. Minimum run size estimates since the 1950s have ranged from 300 to 5,700 chum. The minimum run size in the lower Columbia, from 1995 through 1999, was estimated to range from 1,500 to 3,300 (ODFW and WDFW 2000 as cited in WDFW 2001: draft).

Annual escapements in Washington waters of the lower Columbia mainstem and tributaries are now probably on the order of 3,000 spawners (WDFW 2000 as cited in WDFW 2001: draft). Most Columbia River chum salmon are now found in the lower Columbia River basin below Bonneville Dam. Small numbers of chum are stilled passed above Bonneville Dam each year (86 chum were counted at Bonneville in 1999), but none have been seen above The Dalles Dam since 1980 (WDFW 2000 as cited in WDFW 2001: draft).

In 1998, lower Columbia River chum salmon were proposed for listing as "threatened" by the National Marine Fisheries Service (NMFS) under the Endangered Species Act (ESA)(LCSCI 1998). On August 2, 1999, all naturally produced chum populations in the Columbia River and its tributaries in Oregon and Washington were listed as threatened (NMFS 2001).

The 1992 SASSI identified three stocks of chum in the lower Columbia River (below Bonneville Dam): Grays River, Hardy Creek and Hamilton Creek. According to WDFW (2001: draft) "genetic analysis has indicated that Grays River chum are significantly different from Hardy Creek and Hamilton Creek chum, however differences between chum in Hardy and Hamilton creeks are not significant, so the two stocks have been combined (L. LeClair, WDFW, memo to J. Hard, and L. Krasnow 1999 and Craig Busack, WDFW, personal communication). The two currently recognized Lower Columbia chum stocks represent two population centers, one in Grays River near the mouth of the Columbia and the other below Bonneville Dam in the mainstem Columbia, including Hardy Creek and Hamilton Creek (Dan Rawding, WDFW, personal comm.)".

Chum salmon are found in low numbers in most other lower Columbia River tributaries. During 1998 chum spawning surveys in November and December, spawners were found in the lower Columbia River tributaries shown below in Table 16.

Table 16: Lower Columbia River tributaries in which chum were found during 1998 spawner surveys with numbers of live spawners plus carcasses observed (Joe Hymer, WDFW, unpublished data).

Tributary	Spawner Number	Tributary	Spawner Number
Skamokawa Creek	2	Washougal River	2
Elochoman River	14	St. Cloud Creek	29
Abernathy Creek	14	Duncan Creek	1
Germany Creek	8	Tanner Creek (OR)	2
NF Lewis	4		

Adopted from WDFW 2001: Draft

Chum have also been observed spawning in the mainstem Columbia River near the Interstate 205 bridge and upriver at Ives Island near the mouth of Hamilton Creek (Joe Hymer: personal comm.).

WDFW received funding from NMFS to conduct extensive chum spawner surveys in the lower Columbia basin in 2000, so more data on spawning locations should be available by the end of 2000.

The status of these other lower Columbia River chum is not known. They may be strays from the larger population centers in the Grays River and Hardy and Hamilton Creeks or they may be remnants of once-larger stocks located throughout the lower Columbia basin. Until sufficient genetic sampling has been conducted on chum in these and other tributaries, the current list of lower Columbia River chum stocks will not change; however, chum are present elsewhere in the Columbia Basin and some may be identified as distinct stocks in future Salmon Stock Inventory revisions (WDFW 2001: draft).

Lake River Subbasin:

Very little is known about the historical run size and distribution of chum in the Lake River Subbasin tributaries. Anecdotal information supports the claim that chum once spawned in the lower reaches of Burnt Bridge, Whipple, and Salmon Creeks (Mai and Cummings 1999; WDF 1951; Bryant 1949). The recent run size and distribution of chum, if any, in these creeks is unknown. TAG members did suggest that springs in the lower reaches of Burnt Bridge Creek could potentially support chum spawning and production.

Chum salmon have also recently been observed spawning in the mainstem Columbia River near the Interstate 205 Bridge (Joe Hymer: personal comm.). These spawning sites are associated with spring-fed areas along the Washington shoreline of the Columbia River.

Washougal River Subbasin:

Minimal amounts of historical data are available for the Washougal Subbasin tributaries. Bryant (1949) doesn't mention the presence of chum salmon in his compilation of survey data from the late 1930's. WDF (1951) estimated escapement of chum from the Washougal River at 1,000 fish. WDF (1973) stated "minor numbers of chum reportedly utilized the lower Washougal in past years". According to various TAG members, the lower reaches of Lacamas Creek supported a large run of chum, and that chum also spawned in the lower reaches of the Little Washougal (at least in some years). Spawning surveys in 1998 found 2 chum salmon within the Washougal River (see Table 16 from WDFW 2001: draft).

Bonneville Tributaries Subbasin:

Historical data on chum salmon distribution notes their presence in most of the tributaries within the Bonneville Tributaries Subbasin (Bryant 1949; WDF 1951, WDF 1973; WDF et al. 1993). However, there is little information on run size for any of these systems other than Hardy and Hamilton Creeks. TAG members placed known chum distribution in the lower reaches of Lawton, Good Bear, Duncan, Hamilton, and Hardy Creeks (see Map A-7). Bryant (1949) noted that a few chum spawned near the mouth of Woodward Creek in 1944. WDF (1951) reported that chum use the lower portion of Gibbons, Walton, St. Cloud, Duncan Creeks, Woodward, Hardy, and Hamilton Creeks. According to this historic report, Hamilton Slough "provides good to excellent spawning area for chum salmon and is heavily utilized by this species" (WDF 1951). WDF (1973) stated that chum salmon in WRIA 28 spawn chiefly in the lower reaches of Hardy and Hamilton Creeks. They reported that annual escapement from these streams near Bonneville Dam averaged about 1,000 fish from 1967-1971.

SASSI (WDF et al. 1993) recognized Hardy and Hamilton Creek chum stocks as two separate stocks based on geographical distribution. However, genetic differences between fall chum in Hardy and Hamilton creeks are not significant, so the two stocks have been combined (WDFW 2001: draft). Under the new Salmon Stock Inventory (SaSI) stock status rating process, the status of both lower Columbia stocks is now **not rated** because no recovery goals for these stocks have been developed. Escapement data collected since the 1993 SASSI report show that the numbers of spawners in the Grays River, Hardy Creek and Hamilton Creek remain low (WDFW 2001: draft).

Chum spawn in the lower 1.5 miles of Hardy Creek, below the railroad bridge. Historically, the area was located on a cattle ranch that has now been incorporated into a National Wildlife Refuge. Habitat restoration, which included fencing and revegetation, has been completed in this area. During the fall of 2000, additional spawning channel habitat was created on the USFWS Refuge to increase spawning habitat for chum (Barndt 2001: personal comm.). Hardy Creek chum are native to the system. Spawning occurs from late November to early January. No hatchery introductions have been made into the system. The chum status in this creek was considered to be healthy by SASSI in 1993; however, the number of spawners remains low (WDFW 2001: draft). Spawning ground counts since the late 1950's indicate stable production, with average annual fish per mile values ranging from 67 to 130 (WDF et al. 1993).

According to SASSI (WDF et al. 1993) chum spawn from the State Route 14 bridge downstream about 1.0 mile in mainstem Hamilton Creek and in a small spring fed tributary known as Spring Channel. Habitat improvement work has been completed in Spring Channel. Hardy Creek chum are native to the Hamilton Creek system. Eyed chum eggs of non-local origin were introduced into Spring Channel in the 1970's with no apparent increase in adult production. Spawning occurs in this stream from late November through early January.

Hamilton Creek chum were considered to be depressed due to a long-term negative trend in spawning ground escapement counts (WDF et al. 1993). Annual spawning ground surveys are conducted. Average annual fish per mile values calculated in mostly ten-year intervals from 1944-1991 indicated a long-term negative trend and a short-term decline (WDF et al 1993). However, according to Joe Hymer (2000: personal comm.) recent chum surveys have documented record or near record counts of chum in the Hamilton Spring Channel. WDFW received funding from NMFS to conduct extensive chum spawner surveys in the lower Columbia basin in 2000, so more data on spawning locations should be available by the end of 2000.

Coastal Cutthroat Trout (Oncorhynchus clarki clarki)

Coastal cutthroat trout exist in Washington State west of the Cascade Crest. They are represented by anadromous and resident life history types. In general, the anadromous form exists below passage barriers, whereas the resident form exists above barriers. In a preliminary status assessment, Leider (1997) found that anadromous cutthroat were at greater risk in the lower Columbia River than in any other area in Washington (LCSCI 1998). Coastal cutthroat trout within the Columbia River/Southwest Washington ESU have been proposed for listing as a “threatened” species under the federal Endangered Species Act (NMFS 2001).

The recently released Salmonid Stock Inventory (SaSI) appendix for Coastal Cutthroat (Blakley et al. 2000) provides the most current information on the status of coastal cutthroat within the lower Columbia River and WRIA 28. Most of the information on coastal cutthroat trout stock status in this chapter comes directly from the SaSI document. SaSI recognizes three coastal cutthroat stock complexes in WRIA 28; Salmon Creek Washougal River, and the Bonneville Tributaries stock complexes.

Lake River Subbasin:

Historical data on distribution and stock status of coastal cutthroat trout is generally lacking for the Lake River Subbasin. Anadromous and resident forms of cutthroat trout are present in Salmon Creek, Burnt Bridge Creek, Lake River, and within Vancouver Lake. Anadromous coastal cutthroat enter the river from July through December and spawn from December through June. Resident fish spawn from February through June. Hatchery origin anadromous cutthroat have been released into Salmon Creek at least since 1952. Currently, 12,000 cutthroat smolts are released each year into this system (Blakley et al. 2000).

The status of the Salmon Creek anadromous cutthroat is unknown because there is insufficient quantitative information to identify a trend in abundance or survival (see Table 17). However, considering the poor condition of the habitat within Salmon Creek and declining trends in Columbia River sport catches, to which anadromous Salmon Creek cutthroat contribute, it is likely that the stock complex is “depressed” (Blakley et al. 2000).

Table 17: WRIA 28 Coastal Cutthroat Stock Status

Coastal Cutthroat Stock	Stock Origin	Production Type	Stock Status
Salmon Creek	Native	Composite	Unknown
Washougal River	Native	Composite	Unknown
Bonneville Tributaries	Native	Wild	Unknown

adapted from Blakley et al. 2000

Spawning ground surveys in Salmon Creek and its tributaries in 1989-1989 (Harvester and Wille 1989) found 7 cutthroat redds in upper Salmon Creek and adult cutthroat in Rock Creek (see Table 9). A dairy manure spill in Mud Creek killed most, if not all, salmon fry and juveniles downstream in Morgan and Salmon Creek in 1987. This may partially explain why cutthroat were only found above Morgan Creek (Harvester and Wille 1989). Harvester and Wille (1989) estimated that the cutthroat population in 1989 was 30 fish.

Smolt trapping on Salmon Creek, 1.5 km upstream from Cougar Creek, captured 662 cutthroat between April 23 and June 3 of 1988 (Harvester and Wille 1989). The estimated total juvenile production from Salmon Creek that year was 764 cutthroat trout.

Using the data from smolt trapping and comprehensive habitat and redd surveys, Harvester and Wille (1989) estimated that cutthroat populations within Salmon Creek were only 3%-8% of their potential size, assuming that habitat requirements for each species were optimized (see Table 10). Harvester and Wille (1989) estimated that the maximum adult population could vary between approximately 340 and 1,100 fish (see Table 18).

Table 18: Salmon Creek Potential Cutthroat Production

Creek Name	0.018 parr/m² parr > 1	0.06 Parr/m² parr > 1	Adults assuming 4% survival
Salmon	6,544	21,800	262/870
Mill	820	2,070	25/80
Morgan	473	1,570	19/63
Curtin	157	500	6/20
Rock	412	1,370	16/55
Woodin	353	1,180	14/47
Totals	8,600	28,500	342/1,137

Two estimates of potential productivity were used to determine potential high and low production.
Adapted from Harvester and Harvester and Wille 1989

The SaSI cutthroat appendix (Blakley et al. 2000) groups Whipple Creek and Burnt Bridge Creek in with the Bonneville Tributaries stock complex based on the proximity of the streams and their habitat similarities. The status of cutthroat stocks in Whipple and Burnt Bridge Creeks is Unknown. However, based on trend data in the Kalama River, declining sport catches in the Columbia River, and poor habitat conditions that limit productivity, stocks in Whipple and Burnt Bridge Creeks are likely in critical condition (Blakley et al. 2000).

Mai and Cummings (1999) found two cutthroat trout in Burnt Bridge Creek at Meadowbrook Marsh while electrofishing in December 1997, but electrofishing at two other sites failed to find any cutthroat. Both cutthroat trout discovered at Meadowbrook Marsh were approximately 11 inches long. Five cutthroat adults were also captured in a weir on Lake River near Felida as part of a fisheries monitoring program for Vancouver Lake from 1982-1984 (Knutzen and Cardwell 1984). The weir was fished continuously for 48 hours periods during December, January, February, June, July, August, and September of 1983 for a total of 750 hours. Approximately half the fish traveling up Lake River could have passed by the weir and the weir was not designed to capture fish smaller than 18 inches fork length. Therefore, the abundance of cutthroat could have been considerably greater than the sampling suggests (Knutzen and Cardwell 1984). Fyke net sampling at entrance to the flushing channel found only one cutthroat juvenile entering Vancouver Lake in 1984 and none in 1983 (Knutzen and Cardwell 1984). Data is lacking on the distribution of cutthroat within other streams within the subbasin.

Washougal River Subbasin:

According to Blakely et al. (2000), anadromous, fluvial, adfluvial and resident forms of cutthroat trout inhabit the Washougal watershed. Anadromous coastal cutthroat are found in the mainstem and most of its tributaries up to Dougan Falls, which is believed to be a barrier in most years to adult passage. Fluvial and resident coastal cutthroat are found throughout the watershed in the upper mainstem and tributaries including Lacamas Creek, the Little Washougal, the North Fork Washougal, Canyon Creek, Timber Creek, and Prospector Creek. Adfluvial fish are found in Lacamas Lake. Anadromous cutthroat enter the river from July through December and spawn from January through June. Fluvial, adfluvial and resident fish spawn from February through June. Washougal River cutthroat are considered a native stock of composite production (see Table 17).

The status of Washougal coastal cutthroat is "unknown" because there is insufficient quantitative information to identify a trend in abundance or survival. Anecdotal information from local residents, combined with generally poor habitat conditions suggest that this stock may be "depressed". It should be noted that hatchery-origin anadromous cutthroat in the Washougal River rebounded in 1995-1996. A hatchery anadromous cutthroat broodstock program was maintained at the Skamania hatchery, and used to release 29,000 cutthroat annually into the Washougal River (Blakley et al. 2000). However, cutthroat are no longer released in the Washougal River (Hymer 2000: personal comm.).

Bonneville Tributaries Subbasin:

Both anadromous and resident coastal cutthroat trout inhabit the small tributaries of the Bonneville subbasin. Anadromous cutthroat enter the streams from September through December and spawn from December through June. Resident fish spawn from February through June. Hamilton Creek is the only stream to have received releases of hatchery-origin anadromous cutthroat. Cutthroat are no longer released into Hamilton Creek, partly in response to potential impacts on chum stocks (Hymer 2000: personal comm.). Overall, the stock of cutthroat in the Bonneville tributary system is considered to be native and is sustained by natural production (see Table 17). The status of the small tributaries stock is unknown because there is insufficient quantitative information to identify a trend in abundance or survival. However, due to trend data in the Kalama River and habitat problems in several streams that limit their ability to produce fish, stock status is likely to be critical, especially in Duncan and Lawton Creeks and depressed in Hamilton, Woodward, Hardy, Gee, and Gibbon's creeks (Blakley et al. 2000).

The USFWS (Barndt et al. 2000: unpublished) conducted stream spawning ground surveys in 1997 and 1998 on Gibbons Creek and its major tributaries. Cutthroat were present in all areas surveyed except the upper reaches of Third Tributary (the third major tributary to Gibbons Creek) and were the only fish present upstream of the natural barrier falls in Wooding Creek. They were most abundant in the lower reaches of the Third Tributary and in Wooding Creek upstream of the natural barrier chute. Cutthroat trout is the most widely distributed salmonid in the Gibbons Creek watershed (Barndt et al. 2000: unpublished).

USFWS staff also conducted smolt outmigrant trapping in 1998 and 1999 (Barndt et al. 2000: unpublished). In 1998, smolt outmigrant trapping began on April 24th and ended June 3. Trapping efforts captured 61 cutthroat smolts, ranging in length from 72 to 267mm (mean 164mm). 26% were one year old, 70% were two years old, and 4% were age three (n=27). Smolt outmigrant trapping began again on March 31, 1999 and ended June 16, 1999. Trapping efforts captured 133 cutthroat smolts in 1999, ranging in size from 136mm to 182mm (mean 170mm) (fry excluded). The age of captured smolts ranged from 27% one year old, 68% two, and 5% three years old (Barndt et al. 2000: unpublished).

HABITAT LIMITING FACTORS BY SUBBASIN

Introduction

This Limiting Factors Analysis report discusses the major habitat factors limiting salmon production within the various subbasins of Water Resource Inventory Area (WRIA) 28. For each subbasin, the report examines the condition of a number of habitat variables including: access problems, floodplain connectivity, streambed sediment conditions, in-channel and riparian conditions, water quantity and quality, and biological processes. Habitat conditions were assessed using a combination of existing data from published and unpublished sources, as well as the professional opinion of members of WRIA 28 Technical Advisory Group (TAG). The following summary provides the reader with some background on each of these habitat variables and explains how each variable may be altered by land use activities and/or patterns.

Categories of Habitat Limiting Factors

Loss of Access to Spawning and Rearing Habitat

This category includes culverts, tide gates, levees, dams, and other artificial structures that restrict access to spawning habitat for adult salmonids or rearing habitat for juveniles. Additional factors considered are low stream flow or temperature conditions that function as barriers during certain times of the year.

Information from the TAG, a number of culvert surveys, and a variety of published documents was used to identify barriers to passage and to develop the Barriers Map (Map A-9) in Appendix A.

Floodplain Conditions:

Floodplains are relatively flat areas adjacent to larger streams and rivers that are periodically inundated during high flows. In a natural state, they allow for the lateral movement of the main channel and provide storage for floodwaters, sediment, and large woody debris. Floodplains generally contain numerous sloughs, side channels, and other features that provide important spawning habitat, rearing habitat, and refugia during high flows. This category includes direct loss of aquatic habitat from human activities in floodplains (such as filling) and disconnection of main channels from floodplains with dikes, levees, and revetments. Disconnection can also result from channel incision caused by changes in hydrology or sediment inputs.

Streambed Sediment Conditions:

Changes in the inputs of fine and coarse sediment to stream channels can have a broad range of effects on salmonid habitat. Increases in coarse sediment can create channel instability and reduce the frequency and volume of pools, while decreases can limit the availability of spawning gravel. Increases in fine sediment can fill in pools, decrease the survival rate of eggs deposited in the gravel, and lower the production of benthic invertebrates. This category addresses these and other sediment-related habitat impacts caused by human activities throughout a watershed. These impacts include increases in sediment input from landslides, roads, agricultural practices, construction activities, and bank erosion; decreases in gravel availability caused by dams and floodplain constrictions, and changes in sediment transport brought about by altered hydrology and reduction of large woody debris.

Channel Conditions:

This category addresses instream habitat characteristics that are not adequately captured by another category, such as bank stability, pools, and large woody debris. Changes in these characteristics are often symptoms of impacts elsewhere in the watershed, which should also be identified in the appropriate category (sediment, riparian, etc.).

Riparian Conditions:

Riparian areas include the land adjacent to streams, rivers, and nearshore environments that interacts with the aquatic environment. This category addresses factors that limit the ability of native riparian vegetation to provide shade, nutrients, bank stability, and a source for large woody debris. Human impacts to riparian function include timber harvest, clearing for agriculture or development, construction of roads, dikes, or other structures, and direct access of livestock to stream channels.

Riparian conditions were mapped in WRIA 28, using 30-meter buffers widths along all anadromous streams and/or Department of Natural Resources (DNR) type 1, 2, and 3 (fish bearing) streams (see Map A-10). Forest cover Geographic Information System (GIS) data developed from 1988 Landsat 5 Thematic Mapper (TM) data, that was updated with 1991 and 1993 TM data, was used to determine riparian cover (Lunetta et al. 1997). Forest cover was broadly categorized into four forest classes based on forest type and age class (see Table 2 in Watershed Characterization**).** The overall thematic accuracy of the 1988 TM-based land-cover categorization was 92 percent (PMR 1993 as cited in Lunetta et al. 1997). The non-forest land cover and most surface water features were derived from 1:250,000-scale U.S. Geological Survey land-cover/land-use data. For more information on how this data was collected and used (see Lunetta et al. 1997).

Riparian buffers were rated as good, poor, or unknown, depending upon the type of forest cover category within the 30-meter buffer. Buffers with early-seral stage forest cover were rated as unknown because of its wide range of coniferous crown cover (from 10 to 70% coniferous crown cover). Also, when a riparian assessment using this data in the Skagit basin was ground-truthed, 88% of the early seral stage category was found to contain enough late- and/or mid-seral stage conifers to be considered a "functioning" riparian area (Tom Loranger 2000, personal comm.). The wide range of conditions within the early seral stage category does not lend itself to a consistent good, fair, or poor rating. Buffers with late- and mid-seral stage forest cover were mapped as "good" riparian habitat, while other lands and non-forested lands were mapped as "poor" habitat. This course scale analysis of riparian conditions provides the best picture available of riparian conditions at the watershed scale, but should not be used to identify specific locations for riparian restoration without verification of existing site conditions.

Water Quality:

Water quality factors addressed by this category include stream temperature, dissolved oxygen, and toxics that directly affect salmonid production. Turbidity is also included, although the sources of sediment problems are addressed in the streambed sediment category. In some cases, fecal coliform problems are identified because they may serve as indicators of other impacts in a watershed, such as direct animal access to streams. Map A-8 in Appendix A illustrates stream segments within WRIA 28 that are listed as water quality impaired on the 1998 303d list by the Washington State Department of Ecology (WDOE 2000).

Water Quantity:

Changes in flow conditions can have a variety of effects on salmonid habitat. Decreased low flows can reduce the availability of summer rearing habitat and contribute to temperature and access problems, while increased peak flows can scour or fill spawning nests. Other alterations to seasonal hydrology can strand fish or limit the availability of habitat at various life stages. All types of hydrologic changes can alter channel and floodplain complexity. This category addresses changes in flow conditions caused by water withdrawals, the presence of roads and impervious surfaces, the operation of dams and diversions, alteration of floodplains and wetlands, the removal of forest cover, as well as a variety of land use practices.

Two watershed characteristics were used to identify peak flow concerns within the Watershed Administration Units (WAUs) of WRIA 28. Where WAUs are both hydrologically immature, defined as <60 % of the watershed with forest stands aged 25 years or more, and have road densities >3 miles of road per square mile the watershed is considered impaired (see Map A-13 in Appendix A). Forest cover data from Lunetta et al. (1997) was used to identify forest stands aged 25 years or less (non-forest and other lands categories were considered to be less than 25 years old).

Estuarine and Nearshore Habitat:

This category addresses habitat impacts that are unique to estuarine and nearshore environments. Estuarine habitat includes areas in and around the mouths of streams extending throughout the area of tidal influence on fresh water. These areas provide especially important rearing habitat and an opportunity for transition between fresh and salt water. Human impacts to these areas include loss of habitat complexity due to filling, dikes, and channelization; and loss of tidal connectivity caused by tidegates.

Nearshore habitat includes intertidal and shallow subtidal saltwater areas adjacent to land that provide transportation and rearing habitat for adult and juvenile fish. Important features of these areas include eelgrass, kelp beds, cover, large woody debris, and the availability of prey species. Impacts include bulkheads, over-water structures, filling, dredging, and alteration of nearshore sediment processes.

The Conservation Commission is only assessing habitat limiting factors within tributaries to the Columbia River, and we are not addressing habitat issues within the Columbia River itself. Therefore, an assessment of estuarine and nearshore habitat is not included in this report.

Lake Habitat:

Lakes can provide important spawning and rearing for salmonids. This category includes human impacts that are unique to lake environments, such as the construction of docks and piers, increases in aquatic vegetation, and the application of herbicides to control plant growth.

Lake habitat was not addressed specifically within this report, but was addressed when it applied to specific habitat limiting factors such as access, floodplain connectivity, water quality, and water quantity.

Biological Processes:

This category addresses impacts to fish from the introduction of exotic plants and animals and also from the loss of ocean-derived nutrients caused by a reduction in the amount of available salmon carcasses.

WRIA 28 was divided into three sub-basins (Lake River, Washougal, and Columbia Gorge Tributaries) for discussion of the habitat limiting factors (see Map 4 in Appendix A for basin boundaries).

Lake River Subbasin

Lake River Subbasin includes all the streams draining into Vancouver Lake and Lake River, as well as the Columbia Slope tributaries that drain into the Columbia River from Lake River to the Washougal River (see Map A-3). Lake River connects the Columbia River to Vancouver Lake, and provides a migration route for anadromous salmonids into Salmon and Whipple Creeks, and eventually through Vancouver Lake into Burnt Bridge Creek.

Salmon Creek is the largest watershed in the subbasin, and it contains some of the most productive habitat in the subbasin. Major tributaries include Rock, Curtain, Mill, Morgan, and Woodin Creeks. The Salmon Creek watershed covers approximately 90 square miles that begins in the eastern portion of Clark County and flows generally west for approximately 26 miles to Lake River (Pacific Groundwater Group 2000). The watershed has experienced significant population growth and suburban and rural development over the last 10 years around the City of Battle Ground, and the unincorporated areas of Hazel Dell and Brush Prairie. Comprehensive stream surveys, which were conducted by the Clark County Conservation District (Harvester and Wille 1989) in 1988-89, provide a substantial amount of the data available on habitat limiting factors within Salmon Creek and its tributaries.

Burnt Bridge Creek is a largely urban creek exhibiting many of the subsequent negative impacts to salmonid habitat (Mai and Cummings 1999; Gaddis 1994). The creek flows westward through the City of Vancouver for approximately 12.9 miles where it discharges into Vancouver Lake (EnviroData Solutions, Inc. 1998). For over half its length, Burnt Bridge Creek flows in deep, narrow, man-made ditch, and portions of the rest of the stream have been partially channelized (Gaddis 1994).

The Columbia Slope tributaries are all small, very steep and short streams that flow into the Columbia between Vancouver Lake and the Washougal River. Most of these streams flow through highly urbanized areas and available habitat has been negatively impacted by urbanization. Data on habitat quantity and quality is extremely limited for most of these streams, but overall habitat conditions are likely degraded in these urbanized streams.

Access:

Many fish passage barriers have been identified and repaired over the last few years within the Lake River Subbasin. However, there are still some significant complete passage barriers, as well as other partial barriers that affect fish passage at least during certain flows or for certain species.

One of the most significant fish passage barriers may be the partial barrier caused by the falls below the Highway 99 Bridge on Salmon Creek (see Figure 3). The 1996 avulsion of Salmon Creek into abandoned gravel ponds initiated a head cut that has resulted in an approximately 4-foot high falls. There is some debate over the severity of the barrier the falls presents to migrating fish. Fish have been spotted stacking up below the barrier during low flows, and passage is at least delayed for certain species at certain flows (TAG). However, when flows increase passage over the falls is likely not a problem. A proposal to fund the installation of a fish ladder at this site is being reviewed by the Lower Columbia River Fish Recovery Board. If this falls is a barrier, it blocks a substantial amount of the habitat available within the entire subbasin.

Other blockages identified by the TAG and Clark County on Salmon Creek and its tributaries include:

- On Morgan Creek, TAG members noted that there were possible barriers above 179th Street where there are private culverts and a number of farming activities that might inhibit passage. Fish passage is likely impaired, especially at low flows, below 182nd Avenue, where the creek runs across cattle pastures in undefined channels.
- In Mud Creek (a Morgan Creek tributary) below 182nd Avenue, low flows and undefined channels also likely inhibit fish passage (TAG). According to Gordon Franklin (2000: personal comm.), reports from the late 1980's suggest that there is also a possible culvert blockage where Mud Creek crosses 182nd Avenue.
- On upper Rock Creek there are private culverts above 259th Street that need assessment and possibly repair.
- On upper Mill Creek at rkm 8.1 there is a stop gate for an artificial pond that blocks fish passage. Another barrier was identified at 179th Street by Clark County (Huntington 1997).
- Woodin (Weaver) Creek has two culverts that were identified as partial passage barriers by Clark County; one at N.E. 199th Street and one at N.E. Caples Road (Huntington 1997).
- Curtin Creek has two barriers in the upper headwaters between Padden Expressway and I-205 formed by a headcut (TAG).
- Salmon Falls at RM 24.1 is a complete natural barrier.
- An inoperable fish passage structure on Baker Creek at 164th Circle blocks all passage to approximately 1 mile of upstream habitat (a number of private culverts downstream of this blockage need assessment to determine if there are other downstream barriers). Figure 4 shows how the stream has undercut the structure in Baker Creek. The fish passage structure is now dewatered as the stream flows around and underneath the structure.

Figure 3: Falls on Salmon Creek at Highway 99

Photo taken on 9/29/00

Figure 4: Failed fish passage structure on Baker Creek at 164th Circle.

Photo taken 9/18/00

Burnt Bridge Creek passage barriers include:

- Two culverts on Burnt Bridge Creek within Royal Oaks Golf Course near Fourth Plain Blvd. and Thurston Way were identified as partial barriers that need additional assessment and possibly repair or replacement.
- A series of concrete flumes with steps between Hazel Dell Avenue and I-5 on Burnt Bridge Creek may also become a barrier at certain flows.

Other passage barriers within the Lake River Subbasin include:

- The opening of the flushing channel in October 1982, raised concern of possible disruption of outmigrating salmonid smolts. Sampling performed from 1982-1984 to support the Port of Vancouver flushing channel and dredging project indicates that salmonids congregate in and adjacent to the flushing channel prior to outmigration. Water velocities at the inflow are estimated to be 1-5 feet per second (fps). This is a higher velocity than can be achieved by juvenile salmonids at maximum burst speed. Impingement against the trash rack grid (opening 5/8 inches by 3 3/8 inches) may occur resulting in higher mortality for salmonids ranging between 4 and 20 inches (Envirosphere 1983). Mortality is dependent on salmonid use of the flushing channel entering Vancouver Lake. Data from sampling in 1984 indicates high concentrations of juvenile salmonids in and around the outlet of the flushing channel during early July (Envirosphere 1985). These conditions need assessment to determine the extent of these potential passage problems (Boyden 2000: personal comm.; Knutzen and Cardwell 1984).
- On the upper end of Whipple Creek, near 149th Street and 157th Street are perched culverts that may be barriers to migration. Approximately 1.5 miles of available habitat exists above these blockages, but an assessment of barrier and potential habitat quality above the blockages would be appropriate before prioritizing repair.
- A culvert under 179th Street on Packard Creek (a tributary to Whipple Creek) forms a barrier that partially blocks approximately 0.7 miles of habitat for coho and steelhead (Huntington 1997).
- Passage is limited in many of the Columbia Slope streams by steep slopes and by numerous railroad and road crossings. There may be areas where reconnection would provide important habitat but specific locations are unknown.

Floodplain Connectivity:

At one time the Vancouver Lake lowlands and Lake River contained a series of overflow channels, sloughs, floodplain wetlands, and shallow lakes that would have provided important rearing habitat for juvenile salmonids within the subbasin, as well as Columbia River smolts migrating to the ocean. Lewis and Clark found prosperous Native American communities within the Vancouver Lake Lowlands and along Lake River that depended largely upon salmon runs for their food sources (EPA 1978).

A 2.5-year long monitoring program (Knutzen and Cardwell 1984), designed to evaluate the effects of the restoration of Vancouver Lake on migratory anadromous and resident fish, found that the a substantial number of juvenile chinook salmon entered Vancouver Lake. Abundance of juvenile salmon within Vancouver Lake generally increased in the spring and decreased toward the summer months as temperatures within the Lake increased. This is consistent with other studies that show chinook juveniles commonly enter backwaters during the spring

(USFWS 1980; Knutzen and Cardwell 1984). Juvenile salmonids were found within Vancouver Lake both before and after the flushing channel was constructed. Chinook juveniles entering the lake before the flushing channel must have swum 10 miles up Lake River to reach the lake. Most of the juvenile chinook captured in the lake in mid-June and July of 1984 were approximately 140 mm, while those in the Columbia River were only 100 mm; suggesting that chinook juveniles experienced excellent growth within Vancouver Lake.

Table 19: Estimated number of Chinook Salmon Juveniles entering Vancouver Lake through the flushing channel (based on fyke net catches)

	Number of Chinook			
	June 1983	July 1983	June 1984	July 1984
Fyke net catch *	51	17	40	4
Average net catch	25.5	8.5	13.3	1.3
Number entering lake/day **	166	55	87	9
Estimated total entering lake	5,000	1,700	2,600	270

*No other salmon or trout were captured in 1983. During June 1984, two coho salmon, one rainbow trout, and one cutthroat trout were captured (all juveniles). During July 1984, one coho salmon was captured.
**Average net efficiency used was the average of all tests (43 recoveries/279 marks = 15.4%). The range of efficiency was 12.4% to 40%.
Adapted from Knutzen and Cardwell 1984

Most of the floodplain habitat within the Vancouver Lake Lowlands and along Lake River has since been altered by industrial development and agriculture. Diking, dredging, draining, and even active pumping have reduced the quantity and quality and connection to these floodplain habitats (USFWS 1989; EPA 1978; USFWS 1978; Dames and Moore 1977). Approximately 12 miles of dikes along the Columbia River and Lake River enclose approximately 3,000 acres in the Vancouver Lake lowlands (Fazio 2000: personal comm.). In the 1978 Environmental Impact Statement on the proposed Vancouver Lake Reclamation Project, the U.S. EPA estimated that under average conditions approximately 2,700 acres of land around Vancouver Lake would experience some degree of annual flooding, and 3,500 acres would be flooded every five years (EPA 1978). Approximately 3,000 acres of this area, is now connected to flooding only when the river exceeds approximately 27 feet (about 4 times this last century)(Fazio 2000: personal comm.).

A project in the early 1980s dredged Vancouver Lake and created a flushing channel that connected the lake to the Columbia River. The primary intent of the project was to improve the water quality and lake conditions for recreational purposes (EPA 1978). As part of the "Rehabilitation of Vancouver Lake Project" it was proposed that approximately 9 million cubic yards of material would be dredged out of Vancouver Lake and deposited on a number of sites around the lake and a flushing channel would be constructed to increase the hydraulic connections with the Columbia River (Stoddard 1982). Jones and Stokes Associates, Inc. (1977) estimated that full implementation of the Vancouver Lake Rehabilitation Plan would have resulted in the loss of between 34% and 69% of the wetland habitat in the study area. The loss of these wetland habitats may have been significant for fish, especially species dependent on shallow wetland habitat (Jones and Stokes Associates, Inc. 1977).

Just west of Lake River, Shillapoo Lake and other floodplain depressions have been diked, drained, filled, and leveled. The railroad runs most of the way along the east bank of Lake

River reducing floodplain function, and dikes have been constructed along most of the west banks and along the west banks of Bachelor Island on the Ridgefield Wildlife Refuge.

Diking, stream adjacent roads, and railroads have also extensively altered the lower floodplains along Whipple Creek and Burnt Bridge Creek. On the lower reaches of Whipple Creek, the railroad dike and culvert restrict floodplain connectivity. Reaches of the channel are also incised due to development impacts, especially within the eastern half of section 17 just downstream from Whipple Creek Park (TAG). The upper reaches of Burnt Bridge Creek historically were a series of interconnected wetlands and marshes (Mai and Cummings 1999). The entire area was eventually ditched and drained so that over half of the main channel now flows in a deep, narrow, man-made ditch, and virtually the entire length of its tributaries has been channelized or placed into underground ditches (Gaddis 1994).

On Salmon Creek, the railroad and the 39th Avenue crossings have altered floodplain connections in the lower floodplain. Dikes along the north side of the creek just downstream of the 36th Avenue crossing disconnect floodplain habitat, and their removal could benefit floodplain connectivity (TAG). Gravel operations diked and disconnected floodplain habitat just below I-5, and the 1996 avulsion of the Salmon Creek into gravel ponds has decreased stream length and increased gradient (USAC 2000). The ballfields, roads, and trails just downstream of Klineline Pond also disconnect the creek from its floodplain (TAG). Stretches of the lower creek have been stabilized with riprap, reducing natural lateral movement within the meander zone, and some of this area is now incised and disconnected at all but the highest flows (TAG).

In the middle reaches of Salmon Creek (Highway 99 to 182nd Avenue) there are a number of road crossings, stream adjacent roads, and bank stabilization projects that have reduced connection to historic floodplain habitat (TAG). There is also evidence of stream downcutting through areas within this reach.

Floodplain connections have also been substantially altered in many of the tributaries to Salmon Creek including:

- The nearly flat upper terraces in the upper basin of Mill Creek contain numerous palustrine wetlands, with emergent and forested wetlands lining the riparian corridors (Wille 1990). Between river kilometer (rkm) 6.2 to rkm 4.5 the stream was ditched in the 1950s (Harvester and Wille 1989). The wetland corridor narrows as the slopes increase in the lower basin, and there is little floodplain. Downcutting has occurred along portions of the creek (Harvester and Wille 1989). There is some floodplain restoration potential between 179th and 206th Streets (TAG).
- Along Curtin Creek there are also numerous wetlands. Previous ditching of the mainstem between NE 88th Street and NE 139th Street has probably contributed to the loss of several large seasonal emergent wetlands in the floodplain, as well as adding to the silt load in the stream (Wille 1990). Curtin Creek has been ditched from approximately one-half mile north to at least a mile south of 119th Street (from rkm 2.2 to rkm 4.5). TAG members noted that there is some private mitigation occurring south of the railroad crossing to increase floodplain and wetland habitat.

- Along Woodin Creek, the stream channel is incised throughout its length and stabilized by a heavy growth of reed canary grass above 199th Street (Harvester and Wille 1989). Homes and businesses line the creek through the City of Battle Ground.
- Morgan Creek is channelized where it runs along 174th Street. Mud Creek, a tributary to Morgan, is channelized in areas between 182nd and 172nd Avenues.
- The Baker Creek channel was illegally ditched and moved from its historic location to create a small lake just above 164th Circle (see Figure 5). The fish ladder, described in the access chapter as a barrier, was subsequently constructed as mitigation for the illegal activities. Baker Creek Road also runs alongside of the creek for approximately ¼ mile reducing floodplain functions.

Figure 5: Baker Creek Lake at 164th Circle

Bank Stability:

Most of the stream systems within the Lake River Subbasin are located within urbanized areas. Many of the urbanized stream systems have been channelized with bank stabilization projects to prevent any lateral movement that might harm development. Even within the more rural areas, agriculture and rural residential development has often worked to constrain the stream within its existing banks. The result is many areas with stable banks, but also with localized bank erosion problems both upstream and downstream from these stabilization projects.

A majority of the banks along Lake River have been diked to protect from flooding and to provide transportation corridors. These dikes are stable and actively maintained. There were some eroding bank problems along Bachelor Island on the Ridgefield Wildlife Refuge after the 1996 floods. These areas were subsequently re-stabilized with riprap.

Stream surveys along Burnt Bridge Creek in 1997-1998 noted isolated occurrences of bank erosion, such as in Leverich Park where the public has access to the water (Mai and Cummings 1999). However, most of the stream banks are stable, especially along a number of reaches of the stream have been channelized and where reed canary grass or Himalayan blackberries cover the banks (Mai and Cummings 1999; Correy 1999)

Historically, lower Salmon Creek meandered across a 600- to 1500-foot wide floodplain (see Figure 6). While there is still some natural lateral movement of the stream, areas within this reach have been rip-rapped, or had some other bank stabilization treatment, to prevent further movement (TAG; USACE 2000). The 1996 avulsion of Salmon Creek into abandoned gravel mining ponds just upstream of I-5 has increased streambank instability in the area by initiating a headward incision to the bridge at Highway 99 (see Figure 3).

Further upstream on Salmon Creek, between I-5 and 182nd Ave., there is a significant bank-erosion problem occurring just north of Pleasant Valley School on the south bank. The high bank is eroding into the creek along an 800-900 foot long stretch (TAG). In the upper reaches above 182nd Avenue, there are some agricultural areas where riparian vegetation was removed and lateral channel movement ensued.

Figure 6: Looking North across lower Salmon Creek floodplain

Picture taken on 9/19/00

Harvester and Wille (1989) conducted habitat inventories along the major tributaries to Salmon Creek in 1988-1989. The following bullets summarize bank stability conditions as noted during those habitat inventories, as well as, input from TAG members.

- Along Mill Creek, livestock access and riparian clearing has reduced streambank stability. CPU has fenced some of the problem areas, but there is still a need to fence livestock out of the stream between 199th and 219th Streets (TAG). Where riparian areas have been cleared, most of the instream channel remains heavily vegetated with reed canary grass (TAG; Harvester and Wille 1989). This provides some bank stability but has reduced instream habitat diversity (TAG).

- TAG members considered Curtin Creek's bank stability "poor".
- Cattle access in the lower end of Morgan Creek, and along the south side of 174th Street has reduced bank stability.
- Mud Creek, below 182nd Avenue runs mainly through pasture and agricultural lands where cattle have access to the stream.
- Bank stability along Baker Creek is largely unknown. However, some erosion is occurring along the channelized portion of the creek upstream from 164th Circle and around the inoperable fish ladder.
- On Rock Creek at Bridge 266 (Allworth Road crossing) bank instability problems need attention.
- Overall bank stability is considered poor along Whipple Creek, with major problems just downstream and as far as one mile upstream of Bridge 11 on 179th Street (TAG)
- Most of Burnt Bridge Creek is channelized along residential and light industrial development and a minimal amount of lateral shifting is allowed to occur (TAG; Mai and Cummings 1999; Gaddis 1994).

Wille (1989) developed streambank habitat ratings for upper Salmon Creek, Rock Creek, Morgan Creek, and Mill Creek that provide an estimate of the stability of the streambanks and the stability of the riparian vegetation. Table 20 lists the ratings for each stream system and Table 21 and Table 22 provide the information on how these rating were measured. As Table 20 shows, Morgan and Mill creeks have largest percentage of unstable banks and eroding streambanks, as well as the least vegetation to prevent additional erosion.

Table 20: Streambank habitat ratings for Salmon, Rock, Morgan, and Mill Creeks

	Value	Upper Salmon Creek	Rock Creek	Morgan Creek	Mill Creek
Soil Alteration Rating	0	31%	54%	1%	21%
	1-25	25%	22%	29%	21%
	26-50	27%	17%	19%	16%
	51-75	14%	7%	17%	3%
	76-100	2%	0	34%	39%
Vegetative Stability Rating	4	56%	75%	48%	46%
	3	35%	18%	32%	29%
	2	6%	7%	12%	17%
	1	0	0	12%	3%

Table 21: Streambank soil alteration rating (from Harvester and Wille 1989)

STREAMBANK SOIL ALTERATION RATING	
RATING (Percent)	DESCRIPTION
0	Streambanks are stable and are not being altered by water flows or animals.
1 to 25	Streambanks are stable, but are being lightly altered along the transect line. Less than 25 percent of the streambank is receiving any kind of stress and if stress is being received, it is very light. Less than 25 percent of the streambank is false, broken down or eroding.
26 to 50	Streambanks are receiving only moderate alteration along the transect line. At least 50 percent of the streambank is in a natural stable condition. Less than 50 percent of the streambank is false, broken down, or eroding. False banks are rated as altered. Alteration is rated as natural, artificial or a combination of the two.
51 to 75	Streambanks have received major alteration along the transect line. Less than 50 percent of the stream-bank is in a stable condition. Over 50 percent of the streambank is false, broken down, or eroding. A false bank that may have gained some stability and cover is still rated natural, artificial or a combination of the two.
76 to 100	Streambanks along the transect line are severely altered. Less than 25 percent of the streambank is in a stable condition. Over 75 percent of the streambank is false, broken down, or eroding. A past damaged bank, now classified as a false bank, that has gained some stability and cover is still rated as altered. Alteration is rated as natural, artificial or a combination of the two.

Table 22: Streambank vegetative stability rating (from Harvester and Wille 1989)

STREAMBANK VEGETATIVE STABILITY RATING	
RATING	DESCRIPTION
4 (excellent)	Over eighty percent of the streambank surfaces are covered by vegetation in vigorous condition or by boulders and rubble. If the streambank is not covered by vegetation, it is protected by materials that do not allow bank erosion.
3 (good)	Fifty to seventy-nine percent of the streambank surfaces are covered by vegetation or by gravel or larger material. Those areas not covered by vegetation are proted by materials that allow only minor erosion.
2 (fair)	Twenty-five to forty-nine percent of the streambank surfaces are covered by vegetation or by gravel or larger material. Those areas not covered by vegetation are covered by amterials that give limited protection.
1 (poor)	Less than twenty-five percent of the streambank surfaces are cvoered by vegetation or by gravel or larger material. That area not covered by vegetation provides little or no control over erosion and the banks are usually eroded each year by high water flows.

Large Woody Debris:

Large Woody Debris (LWD) is generally lacking in all systems within the Lake River subbasin, which is common in most streams throughout Western Washington. LWD has been actively removed from streams for flood control, navigation, firewood, and mistakenly to enhance passage for anadromous fish. Logging and development within riparian areas has also eliminated many of the mature conifers that would become the new source of instream LWD recruitment.

Currently, quantities of LWD or other sources of instream cover are limited within Lake River and the Vancouver Lake lowlands (TAG). The lack of cover reduces habitat diversity and available cover for juveniles rearing within or migrating through these areas. Recruitment potential for future LWD is also low since a major supply of LWD to Vancouver Lake and Lake River was cut off when upstream overflow channels, such as Mulligan Slough were disconnected by development along the Columbia. Also, the railroad tracks, agricultural development, and diking along the Lake and Lake River have removed most existing mature riparian vegetation and continue to remove trees that could provide new sources of instream LWD.

Burnt Bridge Creek, Whipple Creek, the Columbia Slope tributaries, Salmon Creek, and all the major tributaries of Salmon Creek have minimal amounts of LWD (TAG; Mai and Cummings 1999; Gaddis 1994; Harvester and Wille 1989). Gaddis (1994) noted that on Burnt Bridge Creek natural riparian plant communities of any significance occur in only a few scattered locations. The same can be said of most of the urbanized reaches of Salmon Creek and the Columbia Slope tributaries. Along the middle, and upper reaches of Salmon Creek there is some LWD recruitment, but even these minor contributions are often removed by property owners or at road crossings (TAG). The only stream system within the subbasin that may have even fair LWD levels is Rock Creek in the upper Salmon Creek watershed (TAG; Harvester and Wille 1989).

Pool Frequency:

Most of the stream systems within the subbasin are lacking pool habitat (TAG; Harvester and Wille 1989; Gaddis 1994; Harvester and Wille 1989). An extensive habitat evaluation of Salmon Creek (Harvester and Wille 1989) found that one of the major factors limiting salmonid production was a lack of diverse pools and riffles for rearing habitat. The lack of pools is related to a general lack of structural LWD that would help force pool development. Without structural LWD, channel scour increases and the spacing of step/pool features increases in many channel types (Rosgen 1996). Urbanization (increased impervious surfaces and decreased forest cover) within watersheds and development along stream corridors also results in alterations to stream channel morphology and potentially a reduction in the quantity and quality of pool habitat due to increased stormwater runoff, peak flows, and fine sediment inputs (Booth 2000; Chamberlin et al. 1991).

Whipple Creek and especially Burnt Bridge Creek are examples of streams where urbanization impacts have decreased the quality and quantity of pool habitat. Whipple Creek has mainly glide habitat with few pools (TAG). The lack of pools is likely tied to the lack of LWD and to scouring from increased stormwater impacts (TAG). Burnt Bridge Creek has very few pools, with mainly riffle and glide habitat (TAG). For much of its length Burnt Bridge Creek is ditched and channelized (Gaddis 1994), and for many years sediment and vegetation were removed each year to maintain it as a drainage ditch (Kunze 2000: personal comm.). The practice of dredging and vegetation removal to maintain flood capacity has been discontinued by the city for the last 2 years.

Lower Salmon Creek below I-5 is mostly a low gradient channel with glide/run habitat and few pools (TAG). Stream surveys (Harvester and Wille 1989) along Salmon Creek from Cougar Creek to 182nd Avenue found that 15% of the surface area was pool habitat, 60% glide habitat, and 16% riffle habitat. The same survey found only 10.8% pool habitat, 41.5% glide habitat, and 47.6 riffle habitat on the upper reaches of Salmon Creek (Harvester and Wille 1989). TAG members felt that the conditions are similar today with generally inadequate pool habitat.

Harvester and Wille (1989) also conducted stream surveys for the major Salmon Creek tributaries and observed the following instream habitat conditions:

- From the mouth of Mill Creek to rkm 8 they determined that 23% of the surface area was pool habitat, 60% glide habitat, and 17% riffle habitat.
- From rkm 2.2 to rkm 4.5, Curtin Creek had been ditched, creating a slough like glide 2.3 km long. On the upper 4.5 km, none of the surface area was pool habitat, over 93% was glide habitat, and 7% was riffle habitat.
- From the mouth of Woodin Creek to 199th Street, 4.3% of the surface area was pool habitat, 15.3% glide habitat, and 80.4% riffle habitat.
- From the mouth of Morgan Creek to the 174th Street culvert, 6% of the surface area was pool habitat, 61% glide habitat, and 34% riffle habitat.
- Along the lower 4.3 km of Rock Creek, 17% of the surface area was pool habitat, 22% glide habitat, and 61% riffle habitat.
- TAG members rated pool habitat in Mud Creek and Baker Creek as "poor" and noted that Baker Creek has essentially one long glide along the channelized portion of the creek.

Side Channel Availability:

Historically, there was likely an abundance of overflow channels, connected wetlands, and small side-channels available for anadromous species in the Lake River subbasin. In the 1978 Environmental Impact Statement (EIS) on the proposed Vancouver Lake Reclamation Project, the U.S. EPA estimated that under average conditions approximately 2,700 acres of land around Vancouver Lake and Lake River would experience some degree of annual flooding, and 3,500 acres would be flooded every five years (EPA 1978). This would include the tidally influenced lower reaches of Salmon Creek and Burnt Bridge Creeks. Large portions of this critical habitat have been disconnected from the river by the existing dike and levee system (Fazio 2000: personal comm.; EPA 1978). Also dredge spoils from the Vancouver Lake Reclamation Project further reduced the amount of off-channel habitat available to salmonids. Jones and Stokes Associates, Inc. (1977) estimated that full implementation of the Vancouver Lake Rehabilitation Plan would have resulted in the loss of between 34% and 69% of the wetland habitat in the study area.

The upper reaches of Burnt Bridge Creek were historically a series of interconnected wetlands and marshes (Mai and Cummings 1999). The entire area was eventually ditched and drained, eliminating side channel along most of the channel (Gaddis 1994). The City of Vancouver continued to dredge sediments and remove vegetation from Burnt Bridge Creek until hydraulic permits were not renewed two years ago (Kunze 2000: personal comm.)

Whipple Creek is mostly a single tread stream with a generally incised channel that has little connection to its floodplain (TAG).

The numbers of side channels formed by channel braiding and meandering has been reduced by filling, channelization, and bank stabilization in the lower Salmon Creek watershed (USAC 2000: Letter). Mining has also created a single thread channel with dikes preventing side channel development just upstream and downstream of I-5. The Army Corps of Engineers is now investigating the feasibility of a proposal to create additional side-channel habitat and enhance various wetland and riparian habitat within the lower Salmon Creek floodplain. Further upstream, between I-5 and 182nd Avenue, there is a general reduction in the amount of side-channel habitat available (TAG). TAG members noted that opportunities to restore side-channel and floodplain habitat existed between 72nd and 182nd Avenues. Above 182nd Avenue, some small dams and private culverts reduce connection to smaller tributaries that could provide habitat characteristics similar to side- and off-channel habitat.

The following tributaries have limited side-channel habitat including:

- Mill Creek is ditched and disconnected from potential side channels along most of its length (TAG; Harvester and Wille 1989).
- Curtin Creek has been ditched from approximately one-half mile north to at least a mile south of 119th Street (from rkm 2.2 to rkm 4.5) (Harvester and Wille 1989).
- Woodin Creek's stream channel is well incised throughout its length (Harvester and Wille 1989).
- Channelization of Baker Creek has reduced side channel availability along Baker Creek Road and above 164th Circle (TAG).
- There is some channelization of Mud Creek, but the extent of the problem is unknown (TAG).

<u>Substrate Fines:</u>

Sedimentation and compaction of spawning substrates appears to be a major problem in most of the streams systems within the Lake River subbasin (TAG; Gaddis 1994; Harvester and Wille 1989). Road densities are used as a surrogate measurement of substrate conditions in the LFA habitat rating standards (see Appendix B), with >3 miles of road per square mile with some valley bottom roads falling in the "poor" category. With 1910.5 miles of roads within only 196.6 square miles in the Lake River Subbasin (Clark County GIS 2000) there is a road density of 9.7 miles per square mile; over three times the road density that would qualify as "poor". Roads contribute significantly to the fine sediment load in many stream systems within the subbasin. Besides the overall road density, stream adjacent roads are also major contributors of fine sediments (see Map A-12 in Appendix A). Lewis County GIS (2000) measured over 44.16 miles of stream adjacent roads (roads within 200 feet of anadromous streams) along streams within the subbasin. Wille (1989) performed extensive stream surveys and habitat evaluations of Salmon Creek and its tributaries and determined that the major limiting factors to salmonid production were sedimentation and compaction of spawning substrates.

Sedimentation problems within Burnt Bridge Creek may be even more acute than in Salmon Creek. Burnt Bridge Creek has mostly sand and silty substrates (TAG; Mai and Cummings 1999; Correy 1999; Gaddis 1994). There are some pockets of spawning substrates between State Route 500 and 4th Plain Blvd., in the Meadowbrook Marsh area, and within the golf course area (TAG); however, Gaddis (1994) noted that these patches of small gravel and cobble are rare and heavily embedded with recent silt. In general, Burnt Bridge Creek flows through urbanized areas with a large percentage of impervious surfaces, receiving inputs of fine sediments from stormwater runoff, development that has encroached on the riparian zones, stream adjacent roads and trails, a cleared BPA corridor, and recreational activities. Very limited suitable spawning habitat remains within Burnt Bridge Creek (TAG).

The substrates in Whipple Creek are generally silt/mud covered, with few suitable spawning gravels available (TAG). Sources for these fines sediments include relatively high road densities, poor riparian conditions, and significant residential and rural development leading to impervious surfaces and stormwater impacts. Initial research found high levels of substrate fines and a subsequent lack of suitable spawning substrates in the stream (Cowan 1999). Excessive sediment inputs from horse trails in Whipple Creek Park also contribute to fine sediment problems within the creek (TAG). There are some spawning substrates still available within Packard Creek, but their condition is unknown.

Salmon Creek avulsed through gravel ponds just upstream of I-5 during the 1996 floods. The consequences of this type of avulsion likely included; mobilization of fine sediments stored in the ponds, the loss of approximately ¼ mile of spawning channel, reduced coarse sediment supply to downstream habitats, and increased streambank and streambed erosion upstream from the avulsion (Norman et al. 1998).

Wille (1989) conducted stream surveys on Salmon Creek and its major tributaries in 1988, and measured the percent of fine sediments within pool, glide, and riffle habitats. The results of those surveys are presented in Table 23. According to the TAG, substrate conditions have probably deteriorated in most systems since the stream surveys of 1997 and 1998. On lower Salmon Creek from Cougar Creek to 182nd Avenue, stream surveys by Wille (1989) determined that fines covered 61.5% of the pool habitat, 9.9% of the glide habitat, and 2.1% of the riffle habitat. The study also determined that 12.1% of the glide habitat and 34.2% of the riffle habitat contained spawning substrates (see Table 23). The TAG noted that a substantial amount of the spawning gravels within this reach are now embedded with fines.

In the upper Salmon Creek watershed (above 182nd Avenue) stream surveys found that fines covered 45.6% of the pool habitat, 14.4% of the glide habitat, and 6.4% of the riffle habitat (Harvester and Wille 1989). The survey also found that 47.6% of the riffle habitat contained spawning substrates. Spawning gravels are still readily available in the upper watershed, but excessive fine sediment inputs and substrate embeddedness continue to be problems.

Stream surveys of Mill Creek (Harvester and Wille 1989) found that livestock had extensive access to the creek. Local farms thoroughly cleared sections of the creek, and excavation and scarification has occurred in and along the creek. No gravel substrates existed in the upper basin, and the streambanks had been trampled and compacted into a muddy slurry (Harvester and Wille 1989). The surveys determined that fines covered 78.4% of the pool habitat, 83.4% of the glide habitat, and 7.6% of the riffle habitat in Mill Creek.

Curtin Creek also has problems with increased fine sediments. Wille (1990) stated that there is an increased silt load in the stream due to loss of adjoining wetlands. From rkm 2.2 to rkm 4.5 the stream is ditched creating a slough like glide with nearly a 100% silt bottom (Harvester and Wille 1989). Stream surveys (Harvester and Wille 1989) determined that fines covered 97.5% of the glide habitat, and 78.8% of the riffle habitat in the creek.

Stream surveys of Woodin Creek determined that fines covered 100% of the pool habitat, 30.5% of the glide habitat, and 21.2% of the riffle habitat. The stream is heavily silted from livestock damage in the riparian zone along the canyon below 199th Street to Caples Road (Harvester and Wille 1989). According to TAG members, small farms could be contributing sediment to the stream near the confluence with Salmon Creek.

Stream surveys in Morgan Creek determined that fines covered 19.3% of the pool habitat, 82.1% of the glide habitat, and 9.3% of the riffle habitat. Fine sediment is apparent in substrates along the lower end of Morgan Creek below 182nd Avenue; however, the quantity and quality of spawning gravel increases above 182nd Avenue.

Tag members also noted that an older dairy farm on a small creek, just downstream of where SR 503 crosses Salmon Creek, runs their cattle in this creek, adding large amounts of fine sediment to downstream habitats. The plume of sediment from this operation is apparent all the way into Salmon Creek even during very low water.

Table 23: Percent of fine sediments in Salmon Creek pool, glide and riffle habitats

Stream Name	% Fines in Pool Habitats	% Fines in Glide Habitats	% Fines in Riffle Habitats
Lower Salmon Creek (Cougar Creek to 182nd Ave.)	61.5%	9.9%	2.1%
Upper Salmon Creek (above 182nd Ave.	45.6%	14.4%	6.4%
Mill Creek	78.4%	83.4%	7.6%
Curtin Creek	(no pool habitat)	97.5%	78.8%
Woodin Creek	100%	30.5%	21.2%
Morgan Creek	19.3%	82.1%	9.3%
Rock Creek	63.8%	3.3%	0.8%

Adapted from Harvester and Wille 1989

Riparian Conditions:

Riparian conditions are generally poor throughout the Lake River subbasin. Extensive diking, fill placement, transportation corridors, agriculture, and residential and commercial development have eliminated most mature riparian vegetation along Lake River, Vancouver Lake, and Burnt Bridge Creek, and the lower reaches of Whipple, Salmon Creeks (see Map A-10). Even at higher elevations, most of the riparian areas have been impacted by rural development, agricultural activities and forest practices. Within the subbasin there are over 44 miles of stream adjacent roads that reduce or eliminate riparian function (see Map A-11)(Lewis County GIS 2000).

Map A-10 in Appendix A displays generalized riparian conditions within a 30-meter buffer along all Department of Natural Resources (DNR) classified 1, 2, or 3 streams within WRIA 28. The forest cover data, from which this map was originally derived, came from 1988 Landsat 5 Thematic Mapper (TM) data and was updated with 1991 and 1993 data (Lunetta et al. 1997). Riparian buffers were rated as good, poor, or unknown, depending upon the type of forest cover category within the 30-meter buffer (see Table 2 in Watershed Conditions Chapter). Buffers with late- and mid-seral stage forest cover were mapped as "good" riparian habitat and other lands and buffers with early-seral stage forest cover were rated as unknown because of its wide range of coniferous crown cover (from 10 to 70% coniferous crown cover)(data from Lunetta et al. 1997 and Lewis County GIS 2000).

Table 24: Riparian Conditions Summary for the Lake River Subbasin

Riparian Conditions	**Good**	**Unknown**	**Poor**	**Total**
Miles within each category	1.5	51.4	151.6	*204.5*
Percentage of total stream miles within each category	1.0 %	25 %	74 %	*100 %*

data from Lunetta et al. 1997 and Lewis County GIS 2000

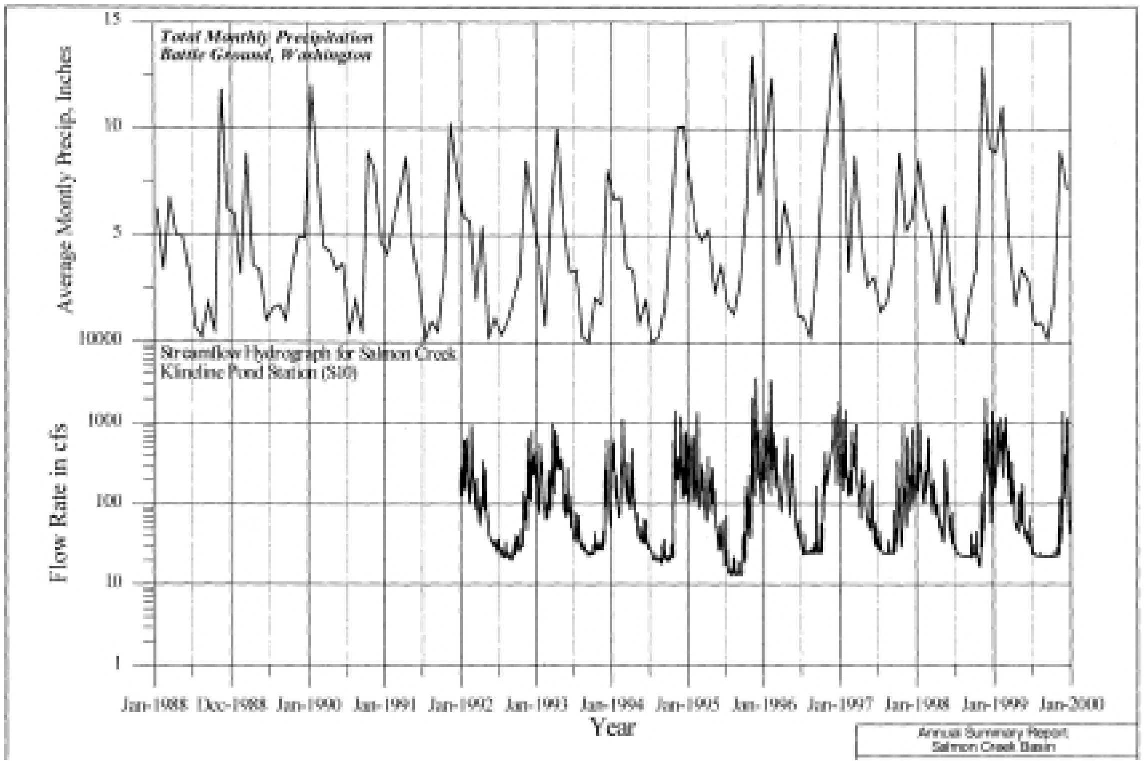
Only a very limited amount (1.0%) of the riparian habitat in the Lake River subbasin is in "good" condition, with the majority of good riparian habitat occurring in the very upper reaches of Rock Creek and above the anadromous zone on Salmon Creek (see Table 24). Early-seral stage vegetation (unknown category) covers 58.5 percent of riparian habitat, and 31.2 percent of riparian habitat falls in the "poor" category.

<u>Water Quantity:</u>

There are no permanent snowpacks, reservoirs, or other impoundments in this subbasin; therefore, stream flow is a direct result of rainfall and groundwater discharge (Pacific Groundwater Group 2000; Wildrick et al. 1998; WDF 1990)(see Figure 7). The lowest streamflow usually occurs in the late summer and early fall during dry weather (Wildrick et al. 1998). Salmon Creek, for example, derives most of its baseflow from groundwater contained within shallow alluvial deposits, and to a lesser extent, groundwater that originates from the Troutdale aquifer system (Pacific Groundwater Group 2000).

The operation of mainstem dams on the Columbia River has altered the flow regime in the Columbia River, and consequently, in Lake River, Vancouver Lake, and the lower reaches of most tributaries within the subbasin

Figure 7: Precipitation and Stream Hydrograph for Salmon Creek



From Pacific Groundwater Group 2000

With the existing streamflow data, it is difficult to separate out changes in streamflow due to alterations in land use and water withdrawals from natural variations due to climate (Wildrick et al. 1998). However, land development that eliminates hydrologically mature forest cover and undisturbed soil can result in significant changes to stream hydrology and, in turn, to the physical stability of stream channels (Booth 2000; Richter et al. 1996; Chamberlin et al. 1991). The flow regime of developed basins commonly increases in magnitude, duration, and frequency of peak flow and decreases in summer baseflows (Morley 2000; Booth and Jackson 1997). These changes in streamflow patterns can have major impacts on stream ecosystems (Booth 2000, Richter et al. 1996).

Substantial changes from historic conditions have occurred in the land cover of the Lake River Subbasin (same area as the Vancouver WAU). Table 25 provides land cover data that was originally derived from 1988 Landsat 5 Thematic Mapper (TM) data and was updated with 1991 and 1993 data (Lunetta et al. 1997). It is apparent from Table 25 that over 87% of the land cover in the subbasin is now in non-forest and other uses (see Table 2 in Watershed Conditions chapter for land cover designations). Subsequently, streams within the subbasin likely experience increased magnitude, duration, and frequency of peak flows and decreased summer baseflows (Morley 2000; Booth and Jackson 1997). In many of the urbanized areas of the subbasin impervious surfaces and increased channel lengths from roads are also likely to contribute to increased peak flows and potentially reduced summer flows (Booth 2000; Furniss et al. 1991). Map A-12 depicts the potential for increased peak flows within each Watershed

Administrative Unit (WAU) of WRIA 28. The Lake River Subbasin (or the Vancouver WAU) is classified as “impaired” because the WAU is both hydrologically immature (< 60% of the basin is covered by ≥ 25-year old trees) and road densities are greater than 3.0 miles of road per square mile.

Table 25: Forest Seral Stage/ Land Cover in the Lake River Subbasin (Acres and Percent Total)

Seral Stage	*Late-Seral*	*Mid-Seral*	*Early-Seral*	*Water*	*Non-Forest*	*Other*	*Total*
Acres	0	7300	1149	7676	86435	23152	125712
Percent	0.00	5.8	0.9	6.1	68.8	18.4	100

From Lunetta et al. 1997

According to Wildrick et al. (1998), streamflow gauging in WRIA 28 has been too sparse and too short-term to detect any changes in streamflow due to water withdrawal, and presently, only Salmon Creek is adequately monitored. However, based on the conceptual model of ground-water/surface-water interactions, pumping of ground water has and will continue to capture and reduce streamflows (Wildrick et al. 1998). Morgan and McFarland (1994) ran computer simulations of groundwater flow within the Portland Basin (including the western portions of WRIA 28) for predevelopment conditions and 1987-88 conditions. These simulations found that: “greater recharge from infiltration of precipitation, and the absence of pumping left more ground water available to discharge to rivers and streams during predevelopment conditions. Discharge to rivers was 33 percent greater and discharge to streams was 18 percent greater than under 1987-88 conditions. Less recharge as a result of more impervious surfaces has decreased the flow rate through the shallow aquifers and decreased discharge to rivers and streams during various seasons. The addition of pumpage near rivers and streams has increased the quantity of seepage from river (from 1 to 36 cfs) and streams (from 48 to 88 cfs) to the ground water system. Streams and rivers throughout the basin received less ground water discharge in 1987-88 than during predevelopment conditions” (Morgan and McFarland 1994 as cited in Wildrick et al. 1998).

Ground water levels (head) have declined five feet or more throughout much of the western portion of WRIA 28. The largest declines (up to 25 feet) in groundwater levels due to withdrawals have occurred in the Troutdale gravel and regolith aquifers within the Burnt Bridge and Salmon Creek drainages (Wildrick et al. 1998). Streams may stop receiving discharge from groundwater and may even become a recharge source to groundwater when pumping lowers groundwater levels. This condition may contribute to natural low flow conditions that already appear to limit production within WRIA 28 (Wildrick et al. 1998). However, water level trends for most of the wells completed by Clark Public Utilities within the alluvial, Upper Troutdale, and Lower Troutdale aquifers have remained stable or risen in the past several years. This is largely due to the increase in precipitation and associated recharge to the basin (Pacific Groundwater Group 2000).

The Washington Department of Ecology (Caldwell et al. 1998) conducted an instream flow study on a number of streams within WRIA 28 during the late summer and early fall of 1998 using the Instream Flow Incremental Methodology (IFIM) and Toe-Width method (see Caldwell et al. 1998). Toe width flows (a way of developing relationships between stream flows and fish habitat requirements) were calculated for a number of tributaries to Salmon Creek and for Whipple Creek. Optimum Toe-Width flows were calculated (see Table 26) and spot flow measurements (see Table 27) were taken for these streams in September, October, and November of 1998. In comparing the optimal toe width flows of Table 26 with the spot flow measurements in Table 27, flows barely approached 50 percent of optimal for rearing in most of these streams by November 1. These are all rainfall-fed streams with small drainage basins. If 1998 were a typical runoff year, it would appear that streamflow likely limits production within these streams (Loranger 2000: letter).

Table 26: Toe-Width Flows for WRIA 28, Salmon/Washougal.

Stream Name	Tributary to	Average Toe Width (in feet)	Toe-Width Flow for Fish Spawning and Rearing (in cfs)					
			Chinook Spawning	Coho Spawning	Chum Spawning	Steelhead Spawning	Steelhead Rearing	Salmon Rearing
Weaver Creek (@ 199th Rd crossing)	Salmon Cr	10.3	24.5	11.7	24.5	23.2	4.5	4.0
Whipple Creek (@ 179th St. crossing)	Lake River	20.3	56.9	28.4	56.9	50.9	11.8	10.6
Mill Creek (@ North Salmon Creek Rd)	Salmon Cr	19.8	55.1	27.5	55.1	49.5	11.4	10.2
Morgan Creek (@ 182nd St. crossing)	Salmon Cr	14	35.9	17.4	35.9	33.1	7.0	6.2
Rock Creek (nr 213th Rd)	Salmon Cr	24.3	71.1	35.9	71.1	62.8	15.2	13.7

Table 27: Spot Flow Measurements by Ecology (WDOE) in cfs

Salmon Creek Tributaries			
Date	*9/3/98*	*10/3/98*	*11/3/98*
Weaver Creek (@ 199th St crossing	0.3	1.3	2.6
Mill Creek (@ North Salmon Creek Rd)	0.5	0.8	1.4
Morgan Creek (@ 182nd St. crossing)	0.6	1.2	2.1
Rock Creek (nr 213th Rd)	0.4	1.7	7.6
Lake River Tributary			
Whipple Creek (@ 179th St. crossing)	2.05	2.7	3.9

Caldwell et al. 1999

Salmon Creek

Table 28 provides a summary of monthly mean and minimum flows for the Northcutt stream gage on Salmon Creek. Monthly mean flows in Salmon Creek have reached as low as 8.6 cfs during August, 1994, and minimum flows fell to or below 12 cfs in 5 of the 10 years on record.

TAG members stated that along with potential low flow problems, peak flows also appear to be elevated in Salmon Creek, and TAG members attributed changes in channel morphology to these increased peak flows. Storm water runoff from development likely contributes substantially to this increase in peak flows (TAG), as does the loss of mature forest cover (Chamberlin et al. 1991).

Mill Creek dries up in most years about mid-July, with the exception of the lower 2 km. Locals recall that prior to 1960, the stream was perennial throughout its length (Harvester and Wille 1989). TAG members noted that there is a substantial storage capacity within the large wetlands of the Mill Creek watershed that help reduce peak flows in Salmon Creek. However, significant planned unit development is occurring within the basin that is reducing storage capacity within the wetland complexes. TAG members felt that stormwater impacts have increased both low flow and peak flow problems. Fish are often stranded in the upper reaches when pools and wetlands are disconnected due to low flow (TAG).

The low-flow problems are significant in the lower end of Morgan Creek where it flows through a number of pastures and farms. Above 182nd Avenue, near the confluence with Baker Creek, flow on Morgan Creek was minimal on 9/19/00. Mud Creek also has low flow problems, especially downstream of 182nd Avenue where the stream becomes seasonal. The extent of low problems in Baker Creek is unknown; however, observed flow was minimal in the creek on 9/19/00. The construction of the pond at 164th Court has likely altered the flow regime of Baker Creek. Springs that once supplied the creek now fill the pond. Rock Creek maintains a fair to good volume of water throughout the year (TAG).

Table 28: **Summary of Monthly Mean and Minimum Flows for Northcutt Gage, Salmon Creek: (Pacific Groundwater Group 2000).**

Month	WY 1988	WY 1989	WY 1992	WY 1993	WY 1994	WY 1995	WY 1996	WY 1997	WY 1998	WY1999	WY 2000
	Average Flows										
Oct		17.5		18.2		72	75	127	169	38	24
Nov		248				528		444	276	330	210
Dec		192		342		843		719	277	510	394
Jan		407		231		388		541	435	466	
Feb		182		83	393			270	265	559	
Mar	247	361		239	181	189		446	259	287	
Apr	205	164		467		177		191	102	118	
May	141	69.4		162	40.4	120		90	180	109	
Jun	94	41.1		84.5	31.2	47.5		88	81	53	
Jul	29.2	28.2			12.6	31.3		41	37	35	
Aug	14.7	23.1			8.6	23	16	27	20	23	
Sep	16.1	16	12.8		11.1	25.2	29	37	21	18	
	Minimum Flows										
Oct		16		12.5	14	8.8	22.2	23	52	20	17
Nov		22				187		107	76	33	20
Dec		68		97		190		168	121	106	93
Jan		120		87.5		127		179	184	163	
Feb		69		55.8	61.3			153	147	195	
Mar	83	140		74	83.9	90		158	120	133	
Apr	89	71		183	60.5	77		97	63	68	
May	67	42		66.6	24.9	40.1		50	53	56	
Jun	38	29		44.3	17.7	28.7		47	49	37	
Jul	16	20			8.5	21.5		27	24	24	
Aug	11	16	9		7.1	18.6	16	21	16	19	
Sep	10	12	8.4	14.1	7.6	17.6	17	22	15	16	
WY Precip.	45.7	49.9	45.1	51.3	36.9	60.8	69.6	74.6	53.4	60.9	

Notes: All flow values are in cfs and precipitation totals are in inches. All data are presented relative to water year (WY).
Water year extends from October 1 to September 30.
Precipitation totals are for Battle Ground monitoring station.

Burnt Bridge Creek

Analysis of flow data from 1974-1994 on Burnt Bridge Creek found a long-term trend of increased flows at the Alki Road stream gage of 0.93 cfs per year, while upstream gages have remained fairly constant (EnviroData Solutions, Inc. 1998). EnviroData Solutions, Inc. (1998) attributed this trend to increasing urbanization upstream from the stream gage.

However, SEH America, Inc. discharges approximately 1 million gallons per day (1.55cfs) to Peterson ditch, a tributary to Burnt Bridge Creek, during the drier months of the year and up to 3 million gallons per day (4.65cfs) during peak rain events in the winter (Yetter 2000: personal comm.). These discharges may benefit salmon during low flow periods; however, an additional 4.65cfs during peak rain events may add to existing peak flow problems in all downstream reaches. This discharge comes from a combination of chemically treated process water, non-contact cooling water, and stormwater runoff. Water to run the plant comes from deep wells that are not hydrologically connected to the stream itself (Yetter 2000: personal comm.).

Columbia Slope Tributaries

The Columbia Slope tributaries (between Vancouver Lake and the Washougal River) are small systems that are fed mainly by springs. Between 1949 and 1988, ground-water discharge to these springs along the Columbia River decreased by approximately 10 cfs, or 42 %. Wildrick et al. (1998) attributes this decline to the pumping of wells in the uplands to the north, because the loss of spring flow corresponds closely in timing with the decline of heads in the aquifers that feed the springs.

Vancouver Lake

The level of Vancouver Lake is determined principally by the level of the Columbia River, and the mean depth and volume varies accordingly (EPA 1978). During the high flows of early summer, the volume of the lake can increase to four times its minimum size, and its mean depth may increase from approximately four feet to 12 feet. During high flows in April, May, and June the flow of water from Lake River into Vancouver Lake can be as high as 200 cfs. When the Columbia River level drops the flow in Lake River reverses and outflows can reach as high as 150 cfs (EPA 1978). Besides the seasonal changes in flow direction within Lake River and Vancouver Lake, flow direction also varies with tidal fluctuations. During low flow periods, the level of the Columbia River at Vancouver rises and falls by as much as two to three feet because of tidal influence. A tidal variation of 2 feet in the Columbia will produce a change in elevation in Vancouver Lake of one to two inches (Dames and Moore 1977).

Alterations of the hydrology of the Columbia River by the operations of mainstem dams, the disconnection of historic overflow channels, and the recently completed flushing channel have all altered the timing, magnitude, and direction of flow within Vancouver Lake and Lake River. These alterations have influenced water quality, the rate of eutrophication, and sediment transport within the system.

Water Quality:

There are some significant water quality problems within many of the stream systems and Vancouver Lake within the Lake River subbasin. Salmon Creek, Burnt Bridge Creek, and Lake River are all listed as impaired streams on the 1998 303d list (WDOE 1998 303d)(see Map A-8 In Appendix A). Vancouver Lake is classified as hyper-eutrophic. It has extraordinarily high phosphorus concentrations with corresponding abundant algal growth and poor water clarity, and the lake is also very shallow with excessive vegetation (WDOE 1995). Vancouver Lake is not on the 303d list because a Phase 1 study has been completed and ongoing control measures are being implemented for Phase 2 (WDOE 2000).

Historical information on Vancouver Lake notes that in the late 1800's the lake was 20-foot deep, clear, and had sturgeon present (Bhagat and Orsborn 1971). There has been a considerable amount of industrial development surrounding the Lake and along streams that drain to the lake. Two superfund sites, the Alcoa (Vancouver Smelter) and the BPA's Ross Complex, are located within the vicinity of the Lake and likely released toxic chemicals into the surrounding ground water and possibly into Cold Creek, a tributary to Burnt Bridge Creek. On both of these sites cleanup activities have been completed, and the sites have been deleted from the National Priority List (U.S. Environmental Protection Agency 2000).

Lake River is listed on Ecology's 303d list (WDOE 2000) for exceedances of state water quality standards for fecal coliform, temperature, and sediment bioassay. Burnt Bridge Creek also has some significant water quality problems. There are documented problems with pH, low DO, high temperatures, and fecal coliform levels (WDOE 2000; EnviroData Solutions, Inc. 1998). Measurements of these water quality parameters have exceeded state standards often enough to include the stream on the 1998 303d list (WDOE 2000). Wildrick et al. (1998) noted that high stream temperatures are exacerbated by low summer flow conditions. Gaddis (1994) conducted a benthic macroinvertebrate study of Burnt Bridge Creek from 1991 through 1992. The results of his study indicate relatively high levels of habitat and water quality degradation in Burnt Bridge Creek. However, Gaddis (1994) did find increases of taxa richness, diversity, and community change index as well as a dramatic decline in filter feeding taxa relative to other sites during the two-year study period downstream of the new Meadowbrook stormwater detention facility. He attributed this change to the "greatly expanded diversity of aquatic and riparian habitats" now available within the 6 acres of open water, marsh, and stream habitat provided within the facility.

Water quality is also a major problem within Salmon Creek and most of its tributaries (WDOE 2000; Wildrick et al. 1998; LCSCI 1998). Salmon Creek is on the 1998 303d (WDOE 2000) list for temperature, turbidity, and fecal coliform exceedances at the 36th Street station. Also, the stream is listed for temperature at RM 6.3 and fecal coliform at Highway 99. Analysis of water quality sampling data finds that Salmon Creek and four of its tributaries have levels of fecal coliform, turbidity, dissolved oxygen, and temperature that frequently violate Class A water quality standards (Pacific Groundwater Group 2000). Intensive development, septic tanks, and agricultural activities all contribute to water quality problems (Pacific Groundwater Group 2000). Low flows also likely contribute to water temperature exceedances in the watershed (TAG). Cougar Canyon Creek, Suds Creek and other smaller tributaries have serious water quality problems and sediment problems, and the cumulative impacts from these streams negatively affect Salmon Creek water quality (TAG). Watershed enhancement projects, instituted by Clark Public Utilities (CPU) and Clark County Conservation District, have reduced erosion, sediment loads, and runoff from animal wastes (Wildrick et al. 1998). However, substantial water quality problems still exist.

Upper Salmon Creek is also on the 1998 303d list for temperature exceedances at RM 16.2, and at Salmon Creek Road, and for fecal coliform exceedances at 156th Street. Small ponds have been constructed on many of the smaller tributaries that feed Salmon Creek and these ponds are contributing to temperature increases and fecal coliform problems within the watershed (TAG).

Mill Creek is also listed of the 1998 303d list for fecal coliform (WDOE 2000). Suspected sources of fecal coliform include septic leakage from areas with high water tables and low gradients (Harvester and Wille 1989). Although summer high water temperature data is not available, high temperatures are thought to be a limiting factor in Mill Creek (Harvester and Wille 1989). Substantial residential development within the basin is likely contributing to water quality problems (TAG).

Curtin Creek contains the highest concentration of wetlands of any subbasin in the Salmon Creek Basin. Water quality is suspect due to non-point source pollution from stormdrains, drainfields, and leachates (Harvester and Wille 1989). Curtin Creek is on the 1998 303d list for fecal coliform (WDOE 2000). According to Wille (1989), high temperatures were thought to be a limiting factor in Curtin Creek. However, 1999 water quality sampling found temperatures within Class A standards 100 % of the time. Curtin Creek also had the fewest exceedances of turbidity levels of any tributary that was monitored within Salmon Creek watershed (Pacific Groundwater Group 2000).

Woodin Creek had major water quality problems until the City of Battle Ground ceased discharging sewage effluent in the Creek in April 1993 (WDOE 1995; WDOE 1989; Wille 1990). However, the Creek is still on the WDOE 1998 303d list for exceedances of the fecal coliform standards; indicating that contamination is from non-point sources (WDOE 1995).

Although summer high water temperature data was not available for Morgan Creek in 1989, high temperatures were thought to be a limiting factor in Morgan Creek (Harvester and Wille 1989). The lack of riparian cover and low flow during the summer months likely contributes to high water temperatures (TAG). Similar problems also contribute to water quality problems in Mud and Baker Creeks (TAG).

TAG members rated water quality as generally "poor" within Rock Creek, with especially large problems occurring between Allworth Road and 259th Street. A number of land uses are contributing to these problems including cattle that have access to the stream along portions of this reach, generally poor riparian conditions, and increasing residential development occurring along the creek.

Water quality conditions are generally unknown on the Columbia Slope Tributaries, but many of these tributaries originate from springs. Residential development, stormwater impacts, and moorages likely negatively affect water quality in these small tributaries and along the Columbia River shoreline.

<u>Biological Processes:</u>
The Conservation Commission is using the number of stocks meeting escapement goals as a surrogate measurement of nutrient levels within stream systems (see Appendix B). Escapement for most anadromous stocks in the Lake River subbasin is likely well below historic averages (WDF et al. 1993: LCSCI 1998), and the lack of carcasses contributing nutrients to the systems may be limiting production within the subbasin. Historical data on the Lake River Subbasin tributaries is lacking. Of all the tributaries within the subbasin, only Salmon Creek is mentioned in the early reports on salmon fisheries. WDF (1951) estimated the escapement of

fall chinook to Salmon Creek amounted to 100 fish. Today, fall chinook are likely extripated from Salmon Creek.

The estimated wild spawner population of winter steelhead in Salmon Creek is less than 100 fish, compared to the wild steelhead escapement goal of 400 fish. WDF et al. (1993) lists Salmon Creek coho as depressed based on chronically low production. Natural coho spawning is presumed to be quite low and subsequent juvenile production is below stream potential (WDF et al. 1993).

Besides low nutrient levels, exotic species like reed canary grass have invaded many of the tributaries within the subbasin. Reed canary grass dominates the extensive floodplain meadow and marsh habitat downstream of Interstate 5 on Salmon Creek. The dense canopy and litter layer associated with reed canary grass precludes the reestablishment of riparian forest on the higher parcels and wapato and other native wetland plants in the lower elevation parcels (USACE 2000). Himalayan blackberries are often the dominant riparian understory vegetation along Salmon Creek and also serve to repress riparian tree, shrub and herbaceous plant establishment in riparian corridors (USACE 2000). Burnt Bridge Creek, Lake River, Vancouver Lake, and most other tributaries in the subbasin have all experienced similar problems with these two invasive species.

Exotic fish species are prevalent and dominate the species assemblage of Vancouver Lake and Lake River. These species are typical of the Columbia River and enter through Lake River or Bachelor Island Slough. Species such as walleye, smallmouth bass, and largemouth bass may prey on juvenile salmonids as they outmigrate to the Columbia River. Competition may also occur from the other exotic species present. Species abundance varies seasonally with salmonids more abundant in the spring. April 1982 seine samples from Vancouver Lake indicate a relative abundance of 0.481 chinook salmon or almost half of the fish species sampled (Envirosphere 1983).

Washougal River Subbasin

The Washougal River Subbasin includes the Washougal River and its tributaries including the Little Washougal, West Fork Washougal, Lacamas Creek, Cougar Creek, Jones Creek, Boulder Creek, Dugan Creek, and a number of other productive streams. The Washougal River watershed encompasses about 240 square miles and flows southwesterly approximately 33 miles to its confluence with the Columbia River at River Mile (RM) 121 at the city of Camas. The lower two miles of the river are located within the Columbia River valley. A narrow, shallow valley characterizes the next eleven miles, and the upper reaches flow through a narrow deep canyon extending into the Yacolt Burn area (Caldwell et al. 1999; WDF 1990).

Significant damage to salmon and steelhead habitat occurred in the early 1900's beginning with the Yacolt Burn, a series of huge forest fires that deforested the upper slopes of the watershed. Following the fires, loggers salvaged the remaining timber from already denuded slopes and built numerous splash dams to flush logs to mills on the lower river (WDF 1990; Parsons unknown date). The effect of these fires, logging, and splash damming on channel morphology is still apparent in the watershed (TAG; WDF 1990). Gravel mining impacted salmon runs by removing much of the spawning gravel in the lower 20 miles of the basin (WDF 1990). Three dams, sited on the lower river, partially blocked passage into much of the basin until they were removed in 1947. Fish also had to contend with toxic sulfite wastes released from the pulp mill that continued to pollute the river well into the 1960's (WDF et al. 1993; WDF 1990; WDF 1951; Bryant 1949).

The cities of Washougal and Camas, located near the mouth of the Washougal River, and the surrounding rural areas have experienced rapid growth over the last 20 years. The resulting urban and rural residential development has contributed to habitat problems within the basin (Caldwell et al. 1999; Wildrick et al. 1998; WDF 1990; WDF 1951). Two hatcheries are located in the Washougal basin. The Washougal Hatchery, located 16 miles east of Camas on the mainstem Washougal, is a major producer of coho and chinook (WDF 1990), whereas the Skamania Hatchery, located on the North Fork Washougal, raises both winter and summer steelhead (WDF 1990).

<u>Access:</u>

Historically, Salmon Falls at RM 14.5 was the first barrier encountered by migrating salmon and steelhead. Steelhead were the only species capable of consistently ascending the falls until a fishway was constructed in the 1950's (WDF 1990). Dugan Falls, at RM 21 (see Figure 8), is generally considered the upstream limit of salmon and winter steelhead migration, while summer steelhead move well into the headwaters (TAG, WDF 1990)(see Map A-3 through A-7 in Appendix A). However, according to Bill McMillan (2000: personal comm.) wild winter steelhead do ascend Dougan Falls in low numbers, and they represent a small, but genetically important part of Washougal River steelhead diversity.

Figure 8: Dugan Falls on the Washougal River

Falls and cascades also limit access to other parts of the watershed including:

- A natural falls on Lacamas Creek at approximately RM 0.9 blocks all upstream passage.

- A falls blocks anadromous passage approximately 600-feet upstream from the mouth of Cougar Creek.
- A bedrock chute at the mouth of Dugan Creek prevents larger fish from accessing the upper reaches.
- Falls block passage into Prospector/Deer Creek approximately 200 yards from the confluence with the Washougal (McMillan 1997: personal comm.).
- Sheetflow across bedrock near the mouth of Meander Creek may restrict passage at times into the upper reaches. TAG members suggest that LWD could reduce water velocities and help develop step pool habitat that would increase access.
- McMillan (1997: letter) also noted that large log jams in the lower reaches of both Bluebird and Silver Creeks have become cemented with gravel accumulating behind the jams. The condition of these jams needs assessment, as the jams potentially restrict passage, and block the movement of gravel to downstream reaches.

Artificial passage barriers also restrict access to various parts of the subbasin including:
- The weir at the Washougal Hatchery diverts summer steelhead into holding ponds until the flows increase, reducing the natural upstream movement of the fish. The hatchery intake dam also presents a potential barrier at low flows (TAG).
- A water intake structure for the Skamania Hatchery at the mouth of Vogel Creek blocks all passage into the stream system (see Figure 9). Passage is blocked to reduce the chance that adult salmon will transmit diseases to the water supply for the hatchery.
- The City of Camas operates small dams on Jones Creek at RM 1.5 and on Boulder Creek at RM 1.5 that block passage to upstream habitat (Quinn 2000: letter). The quantity and quality of available habitat upstream of these structures is unknown. A natural 6-foot waterfall below the dam at RM 1.0 on Boulder Creek may already limit access to all species other than steelhead (Quinn 2000: letter). TAG members report that good habitat exists above the dam on Jones Creek.
- Fish screens on the intakes for Jones and Boulder Creek dams may also affect juvenile fish passage. According to Quinn (2000: letter) Steve Manlow of WDFW inspected the fish screens on both Jones and Boulder Creeks during a field visit. He said that the screening system was adequate, except that the screens had approximately1/4-inch openings instead of 1/8-inch openings required by Washington State Code and the NMFS Juvenile Fish Screen Criteria. The species potentially impacted by these screens include resident cutthroat and rainbow trout in the upper watershed. It is anticipated that the screen mesh size will be upgraded in the near future.
- Longview Fiber operates a 30- to 40-foot high dam on Wild boy Creek that is a complete passage barrier. Longview Fiber does not have any immediate use or plans for the Dam or reservoir, but Steve Hanson (2000: personal comm.) suggested that Longview Fiber has considered selling the property for summer homes. The dam blocks access to approximately 1.7 miles of good habitat for three species (see Table 4). The size of the dam and the amount of sediment perched behind the dam would make removal very expensive (Hanson 2000: personal comm.).

Seven culverts were identified as partial or blocking barriers in the Washougal basin by the Clark County Culvert Inventory (Huntington 1997) including:
- Dial Creek has a barrier above a natural falls that blocks anadromous passage (TAG; Huntington 1997).

- An Unnamed tributary to the Little Washougal at N.E. Blair Road has a partially blocking culvert; however, this stream was not identified as having anadromous fish.
- An Unnamed tributary to the Washougal that was not identified as having anadromous fish has a barrier in Section 32.
- Winters Creek has a partial to total barrier, but it is also above the anadromous zone.
- A partial and transient velocity barrier on Coyote Creek under the Washougal River Road (Section 32 tributary) that is in the process of being repaired or replaced.
- Jones Creek has a partial barrier (likely at least a juvenile barrier) under the Boulder Creek Road (Huntington 1997; TAG).
- Winkler Creek has a partial to total barrier that blocks access to approximately 0.78 miles of habitat at N.E. Borin Road; particularly at low and high flows. This culvert is slated for removal by Clark County.

Figure 9: Water Intake Structure on Vogel Creek

There are also a number of small tributaries that could provide small amounts of rearing habitat for coho, steelhead, and cutthroat that have blockages near their confluences with the Little Washougal including: Jackson Creek, Cotter Creek, and Larson Creek at Stauffer Road, and other unnamed streams. A perched culvert on Timber Creek on state land near Miller Gate Crossing may also affect passage (TAG).

<u>Floodplain Connectivity:</u>

Various past land uses have reduced floodplain and associated wetlands habitat within the Washougal River watershed. Extensive splash damming, logging, and the loss of cover after the Yacolt Burn has left a channel that is scoured to bedrock and incised in many areas (WDF 1990; WDF 1951). These alterations have disconnected the mainstem from historical side-channel and floodplain habitat limiting available rearing and overwintering habitat within the watershed and likely affecting overwinter survival (TAG; Cowan 2000: letter; WDF et al. 1993).

Floodplain connectivity has been seriously reduced by various land use activities in the lower Washougal subbasin (TAG; WDF et al. 1993; WDF 1990). Most of the north side of the Camas Slough has been riprapped to protect the industrial sites. Floodplain connectivity and available habitat in the Camas Slough was also reduced with the filling of Lady Island to construct SR 14 and the railroad crossing (TAG).

A large proportion of the lower Washougal from the mouth to Little Washougal at RM 5.6 has been diked and riprapped, with past and ongoing development occurring within the floodplain (TAG). Diking along the abandoned gravel pits adjacent to the lower river on the south bank has reduced connectivity to off channel habitats except during higher flows, with the possible result that fish are then stranded (TAG). A large reach along the east bank of Schmidt's property, near 32nd Street and K Street, has also been diked and disconnected from the river (TAG). TAG members suggested that the channel is also somewhat incised in this reach.

Public parks protect most of the Lower Lacamas Creek upstream from the 3rd Avenue from development impacts. The potential to improve floodplain and side-channel habitat exists along this protected, vegetated corridor.

Between the confluence with the Little Washougal (RM 5.6) and Salmon Falls at RM 14.5, the Washougal River channel is generally a single thread system entrenched in bedrock, with some areas lined with riprap (TAG). The upper reaches flow through a narrow deep canyon with minimal floodplain development (Caldwell et al. 1999; WDF 1990). Stream adjacent roads run along most of the river to the headwaters, reducing the possibility of additional floodplain development (see Map A-11). Fires, past logging, splash damming, LWD removal, and ongoing land use activities have all contributed to a channel that has incised down to bedrock in many areas.

Development along the Little Washougal and its tributaries has also altered floodplain connections in the Little Washougal watershed. Riprap, dikes and filling to protect residential development and enhance agricultural lands have reduced floodplain connections and available habitat (McMillan 2000: personal comm.). Stream adjacent roads (Blair and the Stauffer Roads) and residential encroachment along Stauffer Road also tend to disconnect the stream from its floodplain. TAG members also noted severe channel incision in areas.

Like the upper mainstem Washougal, the West Fork Washougal is largely a single thread steam confined within a steep canyon (TAG).

Two small creeks that do not appear on the 1:24,000 DNR hydrography layer (they are not typed as fish bearing streams) could provide important rearing and potentially spawning habitat. School House Creek is an unnamed and unnumbered tributary to the Washougal River that enters the Washougal near the WDFW boat launch above RM 13, just across the Skamania County line. This is a low-gradient, spring-fed stream with good water quality. Where the creek now crosses Washougal River Road and Malfait Tract Road there is a 100-foot long blocking culvert. The potential exists to restore some off-channel habitat and forested wetlands by diverting the creek to the west into another stream and through another passable culvert. This would open a substantial amount of rearing habitat that is presently very limited within the Washougal Subbasin. The stream could also potentially provide additional tributary spawning habitat for steelhead, coho, and cutthroat trout.

Slough Creek, another unnamed, unnumbered tributary to the Washougal River, enters the Washougal above the Vernon Road Bridge (approximately RM 14). It is a spring fed side-channel of the Washougal that provides good rearing and potentially spawning habitat for steelhead, coho, and cutthroat trout. The bridge crossing altered the existing stream channel, and three homes occupy the floodplain and reduce floodplain connectivity.

<u>Bank Stability:</u>

Streambanks are generally stable along the Camas Slough and lower Washougal, since much of the area has been riprapped and/or diked. Further upstream streambanks are largely bedrock and stable as well. However, areas with localized erosion and instability occur. A hillside on the south side of the Washougal just downstream from the Vernon Road Bridge has been destabilized by a road cut across the hillside and by subsequent clearing and construction of an off road track (TAG; McMillan, Ed 2000; personal comm.). The unstable area is very large, with the potential to cause significant problems for the Washougal River drainage, even the potential to temporarily block the Washougal River (TAG; McMillan, Ed 2000: Personal comm.). This slide is part of an historic slide, as large as 1.5 miles across and ¾ of a mile deep (McMillan, Ed 2000: Personal comm.). Clark County is monitoring the progress of the slide and it appears that there may not be any way to stabilize the slope (TAG; McMillan, Ed 2000). The immediacy of the problem is unknown at this time.

Another unstable area noted with localized erosion was just below Salmon Falls. According to Bill McMillan (2000: letter), ever since the 1977 flood the island just downstream of the falls has continuously eroded away. The erosion has provided needed recruitment of gravel to the mid-Washougal. However, the entire side of the bluff continues to fall away where homes have cleared the vegetation from the edge of that bluff (McMillan 2000: personal comm.).

Overall bank stability was considered "fair to good" along the Little Washougal and most of its tributaries, with some localized erosion above natural rates (TAG). The most significant erosion along the Little Washougal occurs below Stauffer Road.

Other localized areas with bank erosion within the subbasin included:

- Both the Moto-Cross activities and cattle access to the stream reduces bank stability in Winkler Creek (TAG; McMillan 2000: personal comm.).
- A culvert at Millers Gate on Timber Creek focuses water into a downstream bank, increasing erosion (TAG).
- Fort James opens a gate at the east end of Oak Park Bridge on S.E. 6th Avenue that allows off-road vehicles access to the river to launch boats. Numerous trucks drive along the riparian zones in the lower river creating localized erosion, eliminating riparian vegetation and preventing reestablishment, and potentially leaking contaminants directly into the river.
- A culvert failure led to a debris flow on East Fork Dugan Creek (TAG; Johnson 2000: personal comm.). This failure actually contributed a huge load of scarce spawning gravel to downstream habitats (see Figure 10).

Figure 10: Gravel deposition at the mouth of Dugan Creek

photo taken January 2001

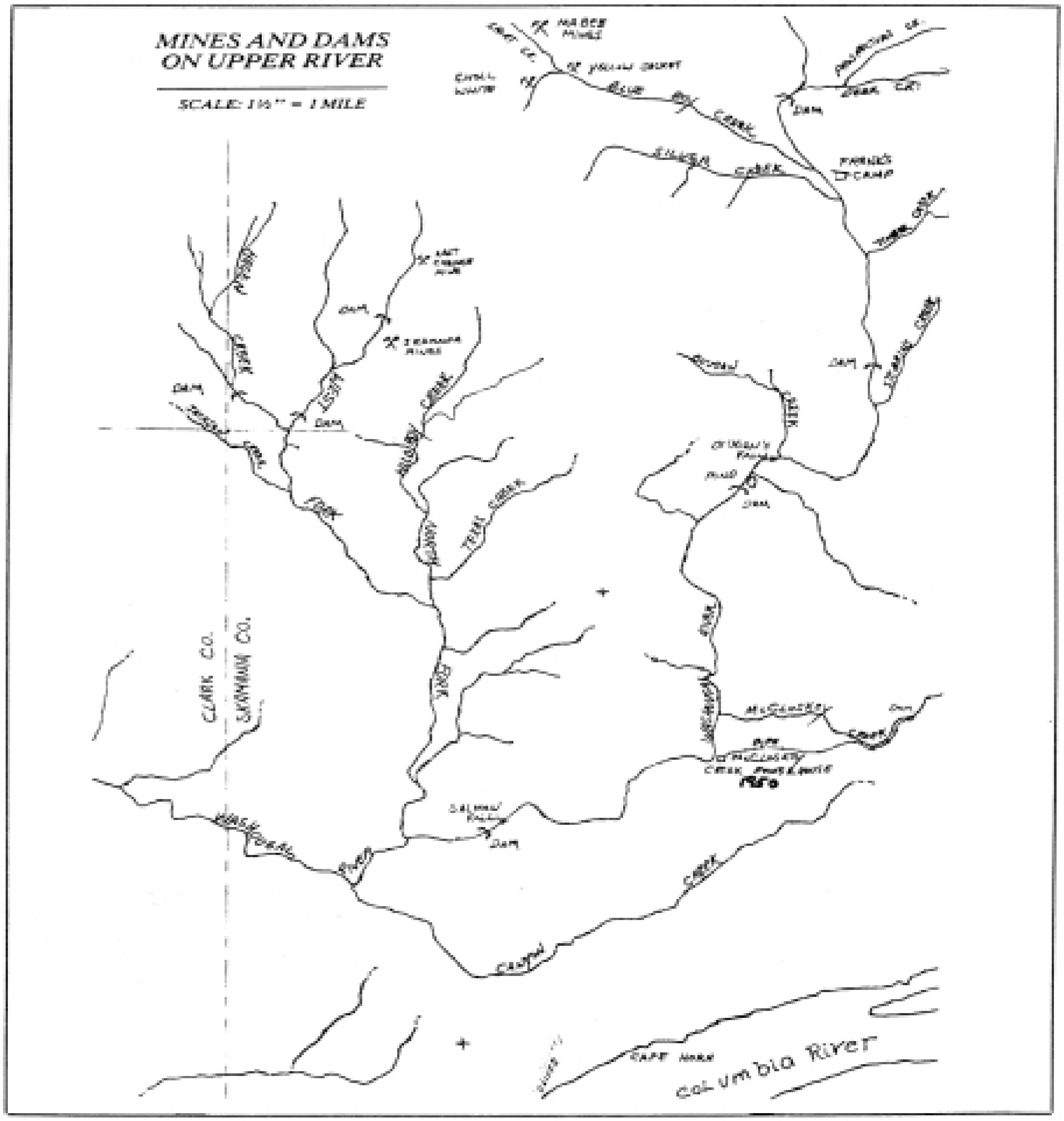
Large Woody Debris (LWD):

LWD was rated poor almost throughout the subbasin (TAG). Extensive splash damming occurred in the early part of the century on the Washougal system (McMillan, Bill 2000: personal comm.; Bryant 1949; Parsons unknown date)(see Figure 11). LWD was either actively removed from many of the channels and/or scoured from the channel when the stored logs were released. Fires in the early century combined with extensive logging after the fires reduced the recruitment of new LWD, and the subsequent logging of second growth forests has further reduced any LWD recruitment potential (McMillan, Bill 2000: Personal comm.; WDF 1990; Parsons unknown date).

Some of the upper portions of the Little Washougal, the West Fork Washougal and mainstem Washougal basin now contain "good" riparian habitat conditions (see Map A-11 data from Lunetta et al. 1997) where near-term recruitment potential is fairly high. Some of the best riparian habitat in the subbasin exists along the lower Lacamas Creek corridor (see Figure 12). Yet, even in this system, few structural pieces of LWD remain in the channel.

LWD is very scarce in the Little Washougal basin, including most tributaries. TAG members stated that LWD supplementation would likely provide substantial benefits in the Little Washougal watershed. LWD supplementation would also benefit a number of other creeks within the subbasin.

Figure 11: Mines and Splash Dams on the upper Washougal River



From Parsons unknown date

Pool Frequency:

Information on pool habitat within the subbasin came almost exclusively from observations of the TAG. No comprehensive data on channel conditions exists for the Washougal and its tributaries. TAG members stated that pool habitat is limited in almost all streams within the subbasin, as structural LWD is also generally lacking. What pool habitat remains in the basin, after the active removal of LWD and the effects of splash damming, is largely controlled by bedrock.

The Camas Slough and the lowest reaches of the Washougal are tidally influenced backwaters of the Columbia. Above the tidal areas on the mainstem Washougal to the Little Washougal confluence the channel contains mainly glides and riffles, with only a few bedrock-formed pools. This lack of pool habitat continues through the middle and into the upper reaches of the mainstem Washougal (TAG). Low flows and extensive recreational use during the summer months further reduce the amount of pool refuge available for adult summer steelhead and juveniles salmonids attempting to rear in the river (McMillan 2000: personal comm.; WDF 1990).

Pool habitat within the Little Washougal and its tributaries is also very limited. This condition is also somewhat attributable to the lack of structural LWD in the stream channels (TAG). TAG members rated pool frequency as poor within the mainstem Little Washougal, Jones and Boulder Creeks, and the East Fork Little Washougal.

Pools within the North Fork Washougal are also infrequent and largely bedrock formed. Of all the streams in the Washougal subbasin that the TAG was familiar with, only Wild Boy Creek has even "fair" pool frequency.

<u>Side Channel Availability:</u>
Reductions in the amount of side channel habitat occurred within the lower Washougal River and the Camas Slough as a result of various land use activities including: gravel mining, the alteration of the Washougal River's entry into the Columbia due to the construction of Ladies Island dike and the State SR 14 Bridge across the Camas Slough in the mid 1960's, industrial development and diking, and the loss of stream adjacent wetlands and beaver ponds (TAG; McMillan 2000: personal comm.; WDF 1990; WDF 1973; WDF 1951). There is a definite need to restore side-channel and off-channel habitat in the lower river (TAG). Mainstem spawning areas are subject to disturbance from extremely high flows, and rearing habitat with refuge from these high flows is limited within the subbasin (TAG).

There is restoration potential for historic side channel habitat within the lower Washougal River at a number of sites including:
- At the abandoned gravel pits just above RM 1,
- Just upstream of 3rd Ave. on Lower Lacamas Creek,
- Below the bowling alley near the 3rd Ave. loop (RM 1.5),
- Near the 17th Street Bridge (RM 3),
- Along Hathaway Park at RM 3.5, and
- Along Schmidt's property upstream of the 17th Street Bridge (approximately RM 4).

Further upstream between RM 5.6 and RM 14.5 the river channel is somewhat incised reducing connection to historic side channels (TAG). However, there were a number of areas noted between RM 13 and RM 14.5 where side-channel habitat still exists including:
- At Slough Creek and the Steel Bridge,
- Near the mouth of Schoolhouse Creek (RM 13.7),

- In an area of wetland complexes on the south side of the river across the river from Schoolhouse Creek,
- At Canyon Creek Road where a culvert blocks access to a wetland complex,
- Just below Salmon Falls.

The upper Washougal is largely a single thread stream that is entrenched down to bedrock, with little potential for development of additional side channel habitat. A large wetland complex located at the Salmon Hatchery (RM 20) has been converted so that the water now runs through the hatchery, eliminating historic access to potentially critical habitat. According to Bill McMillan (2000: personal comm.), "this series of wetlands, ponds, and the creek continue upstream nearly to Dougan Falls in that same extended flat the hatchery facility is built on". It may be possible to reconnect that wetland/creek system back into the Washougal, and provide additional side channel spawning and rearing habitat.

Side Channel availability is generally either unknown or poor for most tributaries within the Washougal Subbasin. TAG members noted that some side channel habitat exists on the Little Washougal River, but overall it is very limited. Tributaries to the Little Washougal (Boulder, Jones, and EF Jones Creeks) also have generally limited side channel habitat available (TAG).

Substrate Fines:

Substrate fines are not considered a major problem within the mainstem Washougal (TAG). High flows regularly rework the sediments in this system. However, roads are likely contributing to the fine sediment load in many stream systems within the subbasin. Road densities are used as a surrogate measurement of substrate conditions in the LFA habitat rating standards (see Appendix B), and >3 miles of road per square mile with some valley bottom roads falls in the "poor" category. With approximately 570 miles of roads, the road density within the Washougal River Subbasin is approximately 2.65 miles of road per square mile (from Lunetta et al. 1997)(see Table 29). This density falls into the fair category for the entire subbasin using the habitat rating standards. However, when broken into smaller subbasins of Watershed Administrative Units (WAUs) road densities fall into the "poor" category in both the Lacamas WAU and Little Washougal WAU (3.28 and 3.36 miles per square mile respectively) (Lunetta et al. 1997). While the upper Washougal WAU has a road density of only 1.38 miles of road per square mile.

Besides the potential overall inputs of fine sediment from high road densities, stream adjacent roads likely contribute to fine sediment loads within stream channels along almost the entire length of the mainstem Washougal, most of the lower Little Washougal, most of Dugan Creek, most of Canyon Creek, and along many other tributaries in the subbasin (see Map A-12 in Appendix A). Table 29 provides data on stream adjacent roads within the WAUs that make up the Washougal Subbasin. Almost 29 miles of roads fall within 200 feet of the anadromous portions of stream systems within the Little Washougal WAU, increasing the possibility that the delivery of fine sediments to the stream systems will be excessive. Many miles of stream adjacent roads also follow stream corridors within other areas of the subbasin. The number of stream crossings per square mile is also included in Table 29. The large number of stream crossings per square mile within the Little Washougal, Silverstar, and Upper Washougal WAUs may alter the movement of sediments through the stream systems within these areas and contribute additional fine sediment to stream channels.

Table 29: Road densities, stream adjacent roads, and stream crossing in the Washougal Subbasin

WAU Name	Road miles outside buffer	Road miles in buffer	Percentage of roads in buffer	Stream Crossings /Sq. Mile	Road Density
LACAMAS	217.3	17.6	7.5	3.5	3.3
LITTLE WASHOUGAL	211.9	29.0	12.0	6.1	3.4
SILVERSTAR	178.3	21.7	10.9	6.3	2.6
UPPER WASHOUGAL	104.0	15.8	13.2	6.5	1.4

Data from Lewis County GIS (2000)

TAG members noted that substrate fines accumulate in the lower end of the Little Washougal. Along with that contribution of fine sediments from roads, extensive residential upstream development is also likely contributing to the fine sediment load in the Little Washougal watershed (TAG). Access to three power line corridors in the Little Washougal watershed is not properly controlled inviting unauthorized ATV use and resulting in major erosion problems (TAG). Vegetation management along these corridors invites ATV use and increases the potential for erosion. Management of these power line corridors should be reviewed and updated to reflect the need to protect critical resources in the area.

An unimproved road and a series of trails parallel both Jones Creek and the East Fork Jones Creek. ATV use is permitted on some trails within this area, and some of these trails are unauthorized and have been closed to public use. However, the DNR does not have adequate resources to consistently patrol ATV use in this area, and the use of many unauthorized trails continues. Erosion from both authorized and unauthorized trails contributes excessive fine sediments to the streams in the area (TAG). Old logging practices scarified the hillsides and stream channels within the East Fork Jones Creek watershed, which also leads to excessive fine sediment inputs (TAG). The stream adjacent access road to the dam on Jones Creek needs assessment and repair to reduce fine sediment inputs (TAG).

In the Winkler Creek watershed, the Washougal Moto-Cross track is another area where ATV use contributes excessive fine sediments to stream systems (TAG; McMillan 2000: personal comm.). Along Winkler Creek a number of pastures need fencing to exclude livestock from the creek (TAG).

TAG members noted that the stream adjacent road along Deer Creek was poorly constructed with a number of problems. These problems have been recently addressed, and hopefully the situation has been stabilized (TAG).

The Dugan Creek watershed contains a number of naturally occurring slides, some of which have been exacerbated by logging and roading on steep unstable ground (TAG). There is a large bedload in Dugan Creek, which Johnson (2000: personal comm.) largely attributes to the contribution from past forest practices. There is a major slide on East Fork Dugan that occurred as a result of a poorly constructed road (TAG; Johnson 2000: personal comm.). TAG members thought that the instability would continue in this area for some time to come. While the impacts from this slide are largely detrimental in the short-term, in the long-term the slide will replenish spawning gravels for downstream habitats.

One problem that is mentioned as a major limiting factor in many previous reports on the Washougal River system is the lack of adequate spawning gravel. Various natural and anthropogenic disturbances have reduced the available spawning gravel in most of the Washougal River channel (TAG; McMillan 2000: personal comm.; Wildrich et al. 1998; WDF 1990; WDF 1973; WDF 1951; Parson unknown date). Gravel mining in the lower river has depleted the spawning gravel supply in the slough and the lower river (TAG; WDF 1990; WDF 1973). The combined hydrologic impacts of the Yacolt Burn and subsequent logging practices, splash damming, and the removal of LWD from the river have left much of the lower 20 miles of the river with exposed bedrock outcroppings and large boulder sections. WDF (1973) noted that the natural chinook spawning production in the Washougal River was limited by a shortage of suitable spawning gravel. Even in the upper mainstem Washougal, spawning gravel is limited with large expanses of exposed bedrock in the channel (TAG). The lack of spawning gravels also occurs in various reaches of other tributaries within the subbasin where elevated peak flows and the lack of LWD has left channels scoured down to bedrock.

Dams on Lacamas Creek and Wild Boy Creek have also eliminated spawning gravel recruitment from upstream sources, and the streams lack adequately sized gravels for spawning (TAG). The 1996 floods may have benefited spawning gravel conditions within lower Lacamas Creek by flushing fine sediments from the spawning substrates (Hutton 2001: personal comm.). Logjams on Bluebird Creek and on Silver Creek may also be reducing gravel recruitment to downstream habitats; these jams need assessment (McMillan 1997: personal comm.).

<u>Riparian Conditions:</u>

Map A-11 in Appendix A displays riparian conditions within a 30-meter buffer along all DNR classified 1, 2, or 3 streams within WRIA 28. The forest cover data, from which this map was originally derived, came from 1988 Landsat 5 Thematic Mapper (TM) data and was updated with 1991 and 1993 data (Lunetta et al. 1997). Riparian buffers were rated as good, poor, or unknown, depending upon the type of forest cover category within the 30-meter buffer (see Table 2 In Watershed Conditions Chapter). Buffers with late- and mid-seral stage forest cover were mapped as "good" riparian habitat and other lands and buffers with early-seral stage forest cover were rated as unknown because of its wide range of coniferous crown cover (from 10 to70% coniferous crown cover)(Lunetta et al. 1997; Lewis County GIS 2000). Table 30 summarizes the number of miles in each category of riparian condition (Good, Unknown, and Poor) within each WAU of the Washougal Subbasin. Table 31 summarizes the percentage of good, unknown, and poor riparian habitat within each WAU. As Table 31 displays, the majority of riparian habitat within the Washougal Subbasin falls in the "Unknown" (or early seral stage) category (for an explanation how riparian conditions were determined see the Riparian Conditions section at the beginning of this chapter).

The Upper Washougal WAU contains the largest percentage of good riparian habitat in the subbasin, while the Lacamas WAU has the least percentage of good riparian habitat (see Table 31). However, only a small fraction of the lower Lacamas WAU contains anadromous habitat, and riparian habitat along lower Lacamas Creek was considered to be some of the best in the Washougal Subbasin (TAG)(see Figure 12).

Table 30: Riparian Conditions Summary for WAUs within the Washougal River Subbasin (Miles)

	Riparian Conditions in each Category (in stream miles)			
WAU Name	**Good**	**Unknown**	**Poor**	**Total Miles**
Lacamas	7.8	34.0	34.9	76.7
Little Washougal	14.3	57.6	23.8	95.7
Silverstar	14.2	52.7	14.1	81.0
Upper Washougal	38.2	43.4	3.6	85.2
Subbasin Total	74.5	187.7	76.4	338.6

Lunetta et al. 1997; Lewis County GIS 2000

Table 31: Riparian Conditions Summary for WAUs within the Washougal River Subbasin (Percent)

	Percentage of Stream Miles in each Category			
WAU Name	**Good**	**Unknown**	**Poor**	**Total**
Lacamas	10.2%	44.3%	45.5%	100%
Little Washougal	14.9%	60.2%	24.9%	100%
Silverstar	17.5%	65.1%	17.4%	100%
Upper Washougal	44.8%	50.9%	4.3%	100%
Subbasin Total (average)	22.0%	55.4%	22.6%	100%

Lunetta et al. 1997; Lewis County GIS 2000

Riparian conditions are especially poor on the north side of the Camas Slough where industrial development has eliminated the riparian cover. Along the south banks of the slough there are a variety of deciduous trees, such as black cottonwood, that would likely be the dominant indigenous species. Map A-11 illustrates the generally poor riparian conditions along the lower few miles of the river. Residential development along the entire northwest side of the river has reduced riparian function in the lower river (TAG). Further upstream (RM 5.6 to RM 14.5) on the mainstem Washougal, riparian conditions are generally fair to good on the south bank, with poor conditions along the north bank where the road parallels the river. As a rule, riparian habitat conditions improve in the mainstem Washougal and in almost all of the tributaries towards the upper reaches. Two exceptions to this rule are the upper reaches of the West Fork and Dugan Creek, where the area is still recovering from the Yacolt Burn (see Map A-11).

Alder and other deciduous trees dominate riparian areas along the Little Washougal watershed, where there is any buffer present. Many areas need riparian restoration, which could be accomplished since good riparian restoration potential exists within the basin (TAG). The Yacolt Burn reduced riparian cover and even soil productivity for many tributaries within the upper Little Washougal watershed. TAG members rated riparian conditions within Boulder, Jones, and East Fork Jones Creeks as poor.

Map A-11 shows that Winkler Creek has clearly poor riparian conditions, and TAG members concurred with this data. TAG members also noted that most of the conifers have been removed from riparian buffers along Texas Creek. As stated, the Yacolt Burn had substantial impacts on the plant community and productivity of the upper reaches of the Washougal and its tributaries. Some of these areas have mostly recovered from the effects of the burn and logging activities afterwards. Other areas such as upper Dugan, Stebbens, Timber, and Prospector are still recovering from the fires and subsequent logging. These areas contain mostly deciduous riparian cover.

Figure 12: Lacamas Creek riparian corridor

Photo taken on 9/25/00

Water Quality:

Some significant water quality problems occur in certain stream systems within the Washougal Subbasin. Lacamas Creek and many of its tributaries are listed as impaired streams on the 1998 303d list (WDOE 2000; WDOE 1996b)(see Map A-8 In Appendix A). Upstream of Lacamas and Round Lakes state water quality standards have often been exceeded for temperature, pH, fecal coliform, and dissolved oxygen (DO). At the outlet from Round Lake into Lacamas Creek, sixty percent of the samples between 1991 and 1992 exceeded state water quality standards for DO, and 65% of the samples exceeded state standards for water temperature (WDOE 2000).

Lacamas Lake also has documented water quality problems. Lake eutrophication was recognized in the 1970's, and a Phase 1 Diagnostic and Restoration study was completed on Lacamas Lake in 1985. With the goal of improving water quality by reducing phosphorus loading, restoration efforts have included implementation of agricultural best management practices (BMPs) throughout the watershed (WDOE 1996b). As of June 1997, the Lacamas Lake Restoration Project had assisted 43 landowners with installation of 105 BMP's (Hutton 2000). Work continues on the cleanup efforts for this lake.

Historically, there were significant water quality problems in the Camas Slough due to the discharges from the paper mill. Early reports on fisheries in the Washougal watershed all mention the harmful effects of sulfite discharges from the mill on fish populations (Bryant 1949; WDF 1951; WDF 1973; WDF 1990). Even as late as the 1960s, fish releases from the salmon hatchery had to be timed so that juvenile fish were passing the pulp mill on vacation weekends when the mill was closed (WDF 1990). Wasteponds were built in the 1970s on Lady's Island to treat mill wastes; however, toxins may still persist in the mud bottom of Camas Slough from the many years of effluent discharge from the Camas paper mill (McMillan 2000: personal comm.). A large cement plant, sited in the lower river, creates runoff that could also be impacting water quality (TAG).

There is somewhat conflicting information available on water quality parameters within the lower Washougal River. Even though there is little data available on water quality within the lower Washougal River, TAG members familiar with the lower Washougal believe that water temperatures are often elevated in the summer months (TAG). According to Dick Johnson (2000: personal comm.), hatchery complex manager on the Washougal River, below milepost 20 temperatures frequently exceed 20°C during the summer. However, water quality monitoring at RM 3.0 found that only one out of nine water samples taken exceeded state water quality standards for water temperature (WDOE 1996). According to WDF (1973), summer water temperatures in the basin tend to be high and reflect the low summer flows, lack of stream bank cover, and ponding of springs behind private dams.

Temperature data was collected on a number of streams within the upper Washougal between 1997-1999 by Clark Skamania Flyfishers and John Sowinski of Washington Trout. Temperature data was collected on West Fork Dugan Creek, East Fork Dugan Creek, Stebbins Creek, Timber Creek, Deer Creek, Prospector Creek, and on the mainstem upper Washougal River between Prospector and Meander Creeks. Table 32 summarizes the approximate high temperatures measured in these streams annually. Consistently high water temperatures were found in Stebbins and Prospector Creeks, and only Timber Creek and Deer Creek had water temperatures that were below 14°C (or considered "good" using LFA rating standards). Even within the upper Washougal mainstem, elevated water temperatures may present problems for juveniles rearing within the system. TAG members suggest that a combination of exposed bedrock, low flows, and poor riparian cover all contribute to the elevated water temperatures in the upper basin.

Table 32: Water Temperatures in the upper Washougal River basin

	Highest Measured Water (in degrees Celcius)		
Data Collection Point	**1997**	**1998**	**1999**
WF Dugan Creek	16.1	15.6	17.8
EF Dugan Creek	16.7	18.3	16.1
Stebbins Creek	17.8	18.9	17.2
Timber Creek	12.8	15.0	13.8
Prospector Creek	17.8	20.0	
Deer Creek			13.8
Upper Washougal	16.7	18.3	

Data from Sowinski 2000

Water temperature data collected at the Washougal Salmon Hatchery between 1987 and 1991 also documents high water temperatures in the upper Washougal basin. During this 5-year recording period, water temperatures at the hatchery frequently exceeded 17.8°C during July, August and September; in some cases for as long as 17 days in a row.

While water quality parameters are generally unknown on the North Fork Washougal, TAG members noted that historically there have been some water quality problems below the hatchery. Bill McMillan (2000: personal comm.) states that the Skamania and Washougal salmon hatcheries release potentially harmful waste effluent, antibiotics, and diseases into the Washougal.

Water quality conditions are unknown for many tributaries to the Washougal. However, TAG members provided qualitative information for some tributaries. TAG members noted that "push-up" dams have been built in the upper Winkler Creek drainage to provide livestock water, and that these tend to increase water temperatures and fine sediment inputs. There has also been extensive grading and clearing along the stream (TAG). Water quality is good within Boulder and East Fork Boulder Creeks. Elevated turbidity levels are considered a potential problem in the Little Washougal, and in both Jones Creek and Dugan Creeks (TAG).

<u>Water Quantity:</u>

Seasonal streamflows in the subbasin follow the same general pattern as precipitation. Since there are no permanent snowpacks, major reservoirs, or other impoundments of the river, stream flow is a direct result of rainfall and groundwater inputs, and flows vary considerably between winter and summer months (see Figure 2 In Watershed Condition Chapter from Wildrick et al. 1998). The 37-year average discharge is 873 cfs, with a peak discharge of 40,400 cfs during the flood of December 1977. The flashy nature of the stream is due, in part, to the topography of the basin as well as natural and human alterations of the environment (mainly the Yacolt Burn that deforested most of the upper watershed)(WDF 1990).

With the existing streamflow data, it is difficult to separate out changes in streamflow due to alterations in land use and/or water withdrawals from natural long-term variations due to climate (Wildrick et al. 1998). However, land development that eliminates hydrologically mature forest cover and undisturbed soil can result in significant changes to stream hydrology and, in turn, to the physical stability of stream channels (Booth 2000; Richter et al. 1996; Chamberlin et al. 1991). The flow regime of developed basins commonly increases in magnitude, duration, and frequency of peak flow and decreases in summer baseflows (Morley 2000; Booth and Jackson 1997). These changes in streamflow patterns can have major impacts on stream ecosystems (Booth 2000, Richter et al. 1996). Table 33 provides data on vegetation cover for each WAU within the subbasin (from Lunetta et al. 1997). It is apparent from Table 33 that well over 40% of the land cover in the Lacamas, Little Washougal, and Silverstar WAUs are now in either "non-forest" and/or "other" uses. These two categories describe areas without mature forest cover including urban areas, agriculture and rangelands, cleared forest, and areas with tree/scrub cover. Subsequently, streams within the subbasin likely experience increased magnitude, duration, and frequency of peak flows and decreased summer baseflows (Morley 2000; Booth and Jackson 1997). In many of the urbanized areas of the subbasin, impervious surfaces and an increase in channel density from road ditches are also likely contributing to increased peak flows and potentially reduced summer flows (Booth 2000; Furniss et al. 1991). WDF (1990) also states that extensive urbanization of the watershed has contributed to runoff fluctuations not conducive to stable flows.

Map A-12 illustrates the potential peak flow concerns within each Watershed Administrative Unit (WAU) of WRIA 28 (Lewis County GIS 2000). The screening criteria used to identify

WAUs within the subbasin with the potential for increased peak flows included WAUs with >3 miles of road per square mile and over 50% hydrologic immaturity based on land cover (hydrologically immature land cover was defined as early seral, non forest, and other forest, exclusive of snow-ice, sand bars, water). Functioning WAUs were considered hydrologically mature (>50% land cover in mature and/or late seral stage vegetation) and had road densities of less than 3.0 miles of road per square mile. Likely Impaired WAUs were either hydrologically immature or had road densities greater than 3.0 miles of road per square mile. Impaired WAUs were both hydrologically immature and had road densities >3.0. As Map A-13 and Table 33 illustrate, only the upper Washougal WAU meets the criteria for a Functioning WAU by having hydrologically mature land cover (>60% mature and/or late seral stage cover) and road densities of <3.0 miles per square mile. All other WAUs were hydrologically immature, and the Lacamas and Little Washougal WAUs had road densities >3. Over 72% of the land cover in the Lacamas WAU falls in either the "non-forest" or "other" category.

Table 33: Forest Seral Stage/ Land Cover in the Washougal Subbasin (Acres and Percent Total)

WAU Name	*Seral Stage*	**Late-Seral**	**Mid-Seral**	**Early-Seral**	**Water**	**Non-Forest**	**Other**	**Total**
Lacamas	**Acres**	11	9103	1505	805	17511	12213	41148
	Percent	0.03	22.1	3.6	2.0	42.6	29.7	100.0
Little Washougal	**Acres**	28	10461	614	510	7917	10710	30241
	Percent	0.1	34.6	2.0	1.7	26.2	35.4	100.0
Silverstar	**Acres**	210	11473	637	0	6147	14221	32689
	Percent	0.6	35.1	2.0	0.0	18.8	43.5	100.0
Upper Washougal	**Acres**	1116	19886	1193	0.0	2971	6525	31690
	Percent	3.5	62.7	3.8	0.0	9.4	20.6	100.0

From Lunetta et.al. 1997

TAG members stated that the Jones Creek watershed is another area with potential peak flow concerns. The watershed is hydrologically immature after the extensive logging that occurred under the old Forest Practice regulations (TAG). Residential development and impervious surface area has also increased substantially within the watershed (TAG).

Low flows are considered a limiting factor in many streams within the subbasin. An instream flow study was conducted for several creeks and rivers in WRIA 28. An Instream Flow Incremental Methodology (IFIM) study was completed for the Washougal River and toe width flows were calculated for the other streams (see Caldwell et al. 1999). The IFIM study was completed for the Washougal River at approximately river mile 3.5. Thirty-six years of streamflow data are available from a USGS gauge at river mile 9.2. December through April median flows on the Washougal are near 1000 cfs, dropping down to near 70 cfs by mid August. This hydrograph (Figure 14) indicates that optimal spawning flows for coho salmon are generally approached by mid October (see Table 34). Optimal chinook spawning flows of 425 cfs are approached by November 1. Optimal steelhead spawning flows of 375 cfs are generally maintained through May. By July 1 median streamflow has dropped to less than optimal flows of 250 cfs for chinook juvenile rearing and far less than optimal flows for steelhead juvenile rearing of 550 cfs. Rearing conditions approach optimal levels for chinook rearing again in October (Loranger 2000: personal comm.).

Stream hydrograph data is also available for the Little Washougal River from a USGS gauging station on river mile 1.0 with a 6-year period of record. Median stream flows in the Little Washougal River range from 100 to 300 cfs in the winter, dropping to around 10 cfs in the summer months. By mid-November median stream flow increases to around 100 cfs, which is optimal for coho spawning (Loranger 2000: personal comm.). Optimal median flows for chinook spawning are not reached during the fall months. Flows are near optimal for steelhead spawning (160 cfs) through mid March. By the first of June and through October, median flows are below optimal for juvenile rearing. In four of those six months flows are less than 50 percent of optimal for juvenile rearing (Loranger 2000: personal comm.).

Water withdrawals for the City of Camas on both Boulder and Jones Creeks affect the hydrology of these streams, as well as the entire Little Washougal watershed (TAG). Withdrawals from Jones and Boulder Creeks are measured at the City of Camas Filtration Plant and totaled approximately 500 million gallons for 1999. Withdrawals from these streams are not metered individually. The City is planning to meter stream withdrawals and streamflows as part of it's watershed planning efforts aimed at providing adequate water for the City's needs while providing adequate flows to protect listed salmonids (Quinn 2000: letter). TAG members considered low flow problems a major limiting factor in both Boulder and Jones Creeks.

In the North Fork Washougal River optimal rearing flow for salmon and steelhead was approached by October 1, 1998. At this time the flows were considerably less than optimal for salmon spawning (see Table 35 and Table 36) (Loranger 2000: letter).

Table 34: Flow and Habitat Relationships for the Washougal River

Species	Instream flow which provides maximum spawning habitat	Instream flow which provides maximum juvenile habitat
Chinook Salmon	425 cfs	225 cfs
Steelhead	375 cfs	525 cfs
Coho Salmon	225 cfs	NA

Adapted from Caldwell et al. 1999

Table 35: Toe-Width Flows for WRIA 28, Salmon/Washougal.

Stream Name	Tributary to	Average Toe Width	Toe-Width Flow for Fish Spawning and Rearing (in cfs)					
			Chinook Spawning	Coho Spawning	Chum Spawning	Steelhead Spawning	Steelhead Rearing	Salmon Rearing
Little Washougal @ HWY 140	Washougal River	54.3 ft.	192.6	103.0	192.6	159.5	47.7	43.8
N.F. Washougal @ Skamania Hatchery	Washougal River	57 ft.	204.6	109.8	204.6	168.7	51.1	46.9

Adapted from Caldwell et al. 1999

Table 36: WRIA 28, Salmon/Washougal, Spot Flow Measurements by Ecology.

WRIA 28 Measured Flows (in cfs)			
Date	9/3/98	10/3/98	11/3/98
Little Washougal River @ HWY 140 crossing	8.2	9.3	26.0
N. F. Washougal River @ Skamania Hatchery	18.8	45.8	

Adapted from Caldwell et al. 1999

The dams on Round Lake alter the natural hydrology of Lacamas Creek and the lower Washougal. Diversions of water from Round Lake into the Mill Ditch and, at times, the release of large amounts of water have altered flows within Lacamas Creek, which used to be a major chum producer (TAG; McMillan 2000: personal comm.). Peter Aller, Facilities Manager at Fort James Camas Paper Mill (2000: personal comm.) stated, "withdrawal from the lake of approximately 35 million gallons per day occur in the winter, fall, and spring months between November and June". However, visual examination of the lake and dam site on October 15, 2000 found that water was already being diverted into the Mill Ditch and that the stoplogs on the dam were in place. The only flow passing the dam into Lacamas Creek on October 15th was a minimal amount of water that escaped through the cracks between the stoplogs (see Figure 13). There are no minimum or maximum flow limitations placed on the operation of the dam according to Steve Young, Environmental Manager for Fort James Inc. (Young 2000: personal comm.). During the summer months lake levels are maintained for recreation, and consequently the creek almost completely dries up (TAG). During an October 15, 2000 site visit it appeared that the lake was at least 2 feet below ordinary high-water mark.

Figure 13: Flow through Round Lake Dam into Lacamas Creek on 10/15/2000

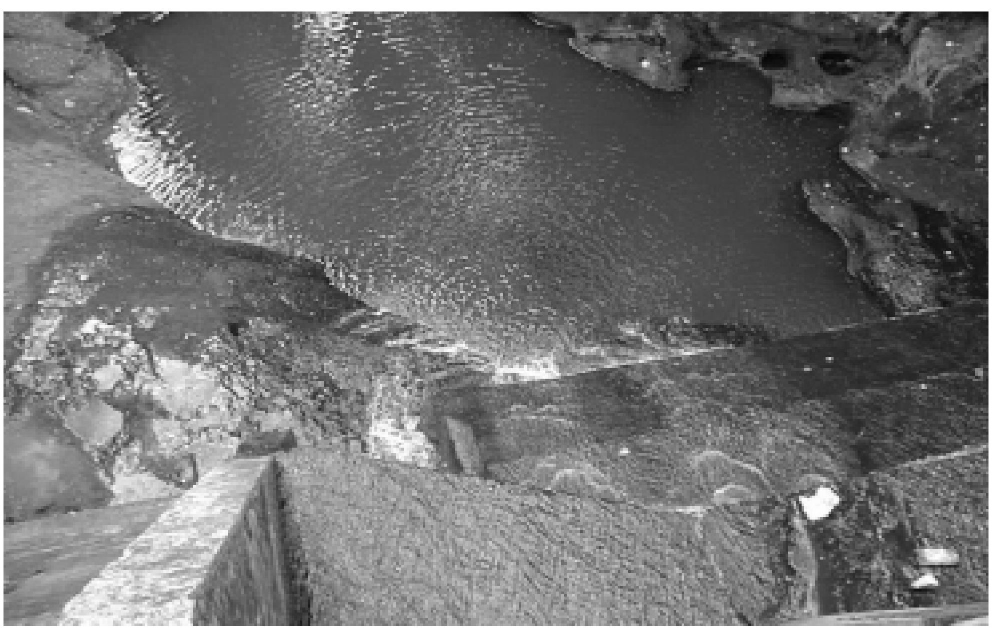
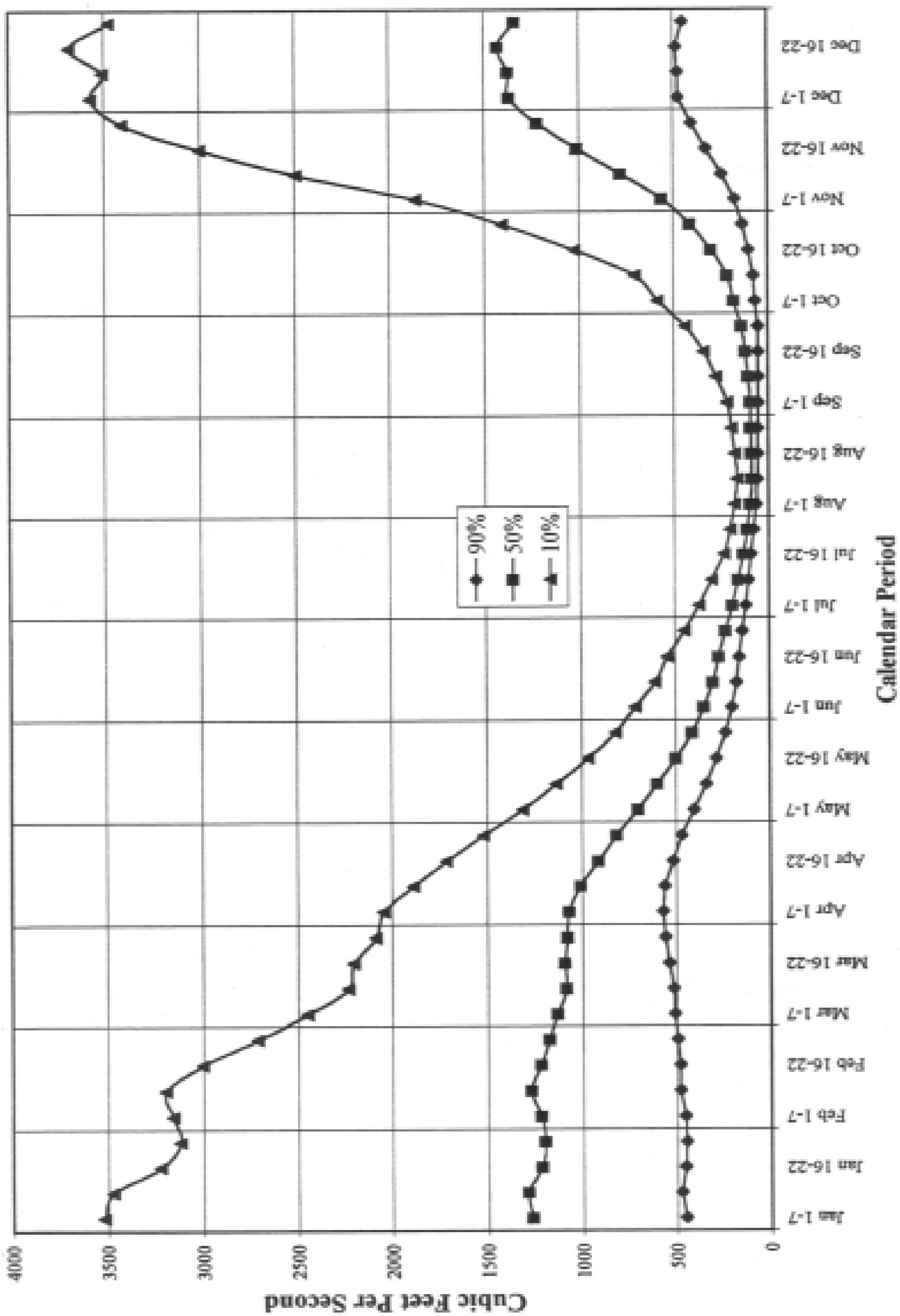


Figure 14: Exceedance probabilities for streamflow, Washougal River near Washougal. USGS Gage 14143500. Period of record 1945-1981 (from Wildrick et al. 1998).



Other areas with low-flow concerns in the subbasin include:

- In the lower Washougal River and Camas Slough, past gravel mining disrupted and reduced subsurface flows to critical chum spawning areas (TAG).
- Low summer flows, combined with high public use above Dugan Falls, negatively impacts the adult population of summer steelhead through harassing and/or killing of holding fish (McMillan 2000: personal comm.; WDF 1990).
- A number of private water diversions (mostly unauthorized) also alter the hydrology of the basin and contribute to low flow problems in the subbasin (TAG; WDF 1973).
- Texas Creek dries up during the summer months (TAG).
- The dam on Wildboy Creek alters the hydrology downstream (TAG).
- Both Schoolhouse and Slough Creeks are spring fed systems that provide good rearing habitat for juveniles. Development threatens the water quantity and quality and habitat within these streams.
- Harvest activities are slated for this year in the Stebbens Creek watershed, increasing peak flow concerns (TAG).

<u>Biological Processes:</u>

The Conservation Commission is using the number of stocks meeting escapement goals as a surrogate measurement of nutrient levels within stream systems (see Appendix B). Escapement for most anadromous stocks in the Washougal River subbasin is likely well below historic averages (LCSCI 1998; WDF et al. 1993; WDF 1990), and the lack of carcasses contributing nutrients to the systems may be limiting production within the subbasin. Historical information on most stocks is lacking, and by the time early investigators conducted fish surveys serious habitat damage had already occurred (WDF 1990). In 1951, the Washington Department of Fisheries estimated minimum coho escapement at 3,000 fish, minimum fall chinook escapement at 3,000 fish, and minimum chum escapement at 1,000 fish.

SASSI (WDF et al. 1993) considered the Washougal River natural spawn fall chinook stock healthy based on escapement trend in 1992, with an average 1,832 fish returning each year between 1967 and 1991 (WDF et al. 1993). Coho stock status on the other hand was depressed based on chronically low production, and natural spawning was presumed to be quite low (WDF et al. 1993). Similarly, both winter and summer steelhead stocks were considered depressed in 1998 due to "chronically low escapements" for summer fish and a "short-term severe decline" for winter fish (LCSCI 1998). Returns of winter steelhead have been only 28% of the escapement goals for the Washougal, and returns of summer steelhead have been <40% of the escapement goals (LCSCI 1998).

Additionally, habitat alterations, non-native introductions, and hatchery practices influence competitive interactions and ecological processes in the Washougal River Subbasin. Higher water temperatures and sluggish flow in the lower Washougal and Camas Slough likely favors both native (pikeminnow) and non-native (bass) predators of salmonids (TAG). Brown trout (non-indigenous) are planted in Lacamas Lake and some make their way down into the Washougal Basin (TAG). Providing fish passage over Salmon Falls in 1956 allowed species/stocks of salmon/steelhead access between Salmon Falls and Dougan Falls; historically an area where passage was blocked. Access by these species potentially impacts summer run steelhead due to increased interspecies and intraspecies competition (McMillan 2000: personal comm.). Waste effluent, antibiotics, and potential disease from millions of hatchery fish from

Skamania and Washougal River Salmon hatcheries likely affects native fish within the North Fork and mainstem of the Washougal Rivers (McMillan 2000: personal comm.). TAG members also suggested the need for a trap on the North Fork Washougal to separate out hatchery fish and reduce interactions between hatchery and wild fish on the spawning grounds.

Bonneville Tributaries Subbasin

The Bonneville Tributaries Subbasin includes all of the tributaries that enter the Columbia River upstream of the Washougal River to Bonneville Dam. The largest and most productive tributaries include Gibbons Creek, Lawton Creek, Duncan Creek, Woodward Creek, Hardy Creek, Hamilton Creek, and Greenleaf Creek. Most of these tributaries are fairly small. In general, theses tributaries have only a limited amount of low gradient spawning habitat in the lower reaches with steep gradients or impassable falls occurring a few miles upstream of the confluence with the Columbia. Many of them are intermittent or have subsurface flow during summer months (WDF 1951; Bryant 1949).

Even though these streams are small, a few provide some of the most productive and critical spawning habitat for chum salmon in the lower Columbia River.

<u>Access:</u>
Historically, a number of significant passage barriers existed on various tributaries in this subbasin. Before 1966, Gibbons Creek flowed across Steigerwald National Wildlife Refuge through a wetland complex before entering the Columbia. In 1966, the area was diked, and the stream was channelized and drained to the west through what is now referred to as the Remnant Channel (Erickson and Tooley 1996; TAG). In 1992, Gibbons Creek was again modified to flow almost due south across the refuge to the Columbia (Post 2000). For most of the lower mile the creek now flows through an artificial, elevated channel before discharging into the Columbia through a fish ladder structure. The channel and structure were constructed to reopen Gibbons Creek to anadromous passage; however, some passage problems still occur.

Figure 15 shows the passage structure at the mouth of Gibbons Creek on October 27, 2000. A combination of low stream flow in Gibbons Creek and in the Columbia River created a two- to three-foot outfall that fish would need to jump.

Along with the outfall, fish would have to pass upstream across a shallow bar at the mouth where only a few inches of water flowing was flowing across it on October 27, 2000 (see Figure 16). While passage may have been affected at the time of this site visit, passage may not be a significant issue during most years, considering that the fall of 2000 had unusually dry conditions and extremely low flows in the Columbia River. However, during dry years these problem areas could affect passage into many miles of productive anadromous habitat.

Figure 15: Gibbons Creek passage structure

Photo taken on October 27, 2000

Figure 16: Mouth of Gibbons Creek 10/27/2000

Photo taken on October 27, 2000

The diversion structure just downstream from State Route 14 presents another passage problem in Gibbons Creek. This structure diverts Gibbons Creek from its old channel, which flowed into Steigerwald Lake, into the elevated channel that empties into the Columbia River. The structure is designed to pass 70 cubic feet per second (cfs) into the elevated channel, and to force excess water through a screened opening into the old channel and the Steigerwald Lake bed. Bedload builds up above the diversion structure during storm events, reducing the flow capacity of the structure (Barndt et al. 2000: unpublished). When the capacity of the elevated channel is exceeded fish are spilled into adjacent fields and stranded (TAG).

The USFWS conducted fish surveys within Gibbons Creek and its major tributaries. The distribution of anadromous fish was limited in the Gibbons Creek watershed by both artificial and natural barriers. Coho and steelhead were found in Gibbons Creek drainage up to the road culvert blockages at Hans Nagel Road, to a road culvert blockage at Q Street on Campen Creek, and to natural barrier falls on Wooding Creek and Tributary Three (stream #281)(Barndt et al. 2000: unpublished) (see Table 37).

Clark County (Huntington 1997) and TAG members also identified some of the same culvert blockages as noted by the USFWS (Brandt et al. 2000: unpublished), as well as other culverts that potentially block access to habitat in Gibbons Creek, including:

- A partial to total barrier on Gibbons Creek at Hans Nagel Road blocks approximately 1.43 miles of the best habitat in the watershed. A 4-foot diameter pipe approximately 12-feet beneath a paved road drops water 4-feet into a nice take-off pool (Huntington 1997).
- A private culvert 200 meters upstream of Hans Nagel Road is a definite barrier due to a perched culvert (TAG).
- Huntington (1997) also identifies a possible velocity barrier at highest flows on the "Third Tributary" to Gibbons (Stream #281). TAG members estimated that there was approximately one-mile of habitat above the block.

Table 37: Fish barrier types and locations in Gibbons Creek drainage.

Reach	Barrier	Distance from confluence (meters)	Distance from headwaters (meters)
Gibbons Creek 3 (GC3)	culvert at Hans Nagel Rd.	6189	2957
Gibbons Creek 3 (GC3)	culvert on private land	6384	2762
Campen Creek 1 (CC1)	culvert at Q Street	2430	3872
Campen Creek 3 (CC3)	culvert at unnamed site	5396	1006
Campen Creek 3 (CC3)	culvert at unnamed site	6098	305
Wooding Creek 2 (WC2)	natural chute	1524	2317
Third Tributary (TT2)	natural falls	1829	1982

From Barndt et al. 2000: unpublished

TAG members identified a number of barriers that potentially block access to habitat in Campen Creek including:

- A stop log structure used to collect irrigation water for the Orchards Hills golf course creates a passage barrier when in place (TAG).
- There are 3 potential barriers located near J Street that the City of Washougal is now assessing for passage.
- Also the Q Street culvert is considered a complete barrier to passage. The Regional Fisheries Enhancement Group has been working on replacing this barrier. Approximately on mile of coho, steelhead, and cutthroat habitat exists on Campen Creek above this blockage (TAG; Barndt et al. 2000: unpublished).

State SR 14 and the railroad parallel the Columbia River along most of this subbasin. Culverts under these corridors affect anadromous passage into a number of tributaries, including:

- The railroad culverts on Indian Mary Creek need assessment to determine their impact on fish passage. TAG members suggested that these culverts at least need cleaning frequently.
- TAG members considered the culvert on Woodward Creek under SR 14 passable, but they also suggested that the culvert did not have the capacity to function properly, and so sediment transport is affected and the road is frequently overtopped.
- TAG members noted that on Hardy Creek the SR 14 and the BN Railroad culverts (at approximately RM 1.4) are both passage barriers. Potential habitat extends to Hardy Falls, approximately 0.94 miles above the railroad culvert (TAG). Greenia Creek, a small tributary to Hardy that runs, through the National Wildlife Refuge, has been diked and screened to prevent fish access. The pond is managed as a western pond turtle refuge (TAG).

Low flow passage problems also exist in many tributaries in this subbasin. In Hamilton Creek, Woodward Creek, Hardy Creek, and Good Bear Creek large bedloads have accumulated in lower gradient reaches near the mouth, and flow becomes subsurface at times during the summer months. Culverts along SR 14 and the railroad likely exacerbate this natural condition as they can alter or constrict the movement of coarse sediments downstream through these systems (TAG).

A dam near the mouth of Duncan Creek has partially blocked passage since its construction in the early 1960's. Historically, Duncan Creek provided good quality spawning habitat for chum salmon. Chum salmon in the lower Columbia specifically target groundwater upwelling areas similar to those found on Duncan Creek. Habitat with appropriate groundwater upwelling is rare within the lower Columbia and protection and enhancement of these areas is key to chum survival. Chum spawning habitat still exists within the impoundment area above the dam, although some restoration work is needed (Joe Hymer 2001: personal comm.).

Prior to the construction of this earthen dam in Duncan Creek, peak chum salmon counts exceeded several hundred fish. After construction of the dam chum counts fell to 4 fish in 1970, and no chum were counted between 1970 and 1995 (Manlow 1998: personal comm.). A recently funded project is underway to restore anadromous fish (steelhead, coho, and chum) passage in Duncan Creek by replacing an existing culvert with a concrete flume fishway (see Figure 17). The existing culvert was a partial passage barrier to steelhead and coho salmon, and was obviously a complete barrier to chum salmon. The new passage structure will provide exceptional benefits to chum salmon by restoring access to historical spawning springs in the lower watershed. Only three other streams in the Lower Columbia River currently support viable chum populations, and all are the subject of extensive passage and habitat improvement projects. Also, approximately 2.5 lineal stream miles of spawning and rearing habitat will become available for coho and steelhead (Prendergast 2000: grant application). Anadromous passage will still be blocked into the creek between June and October so that the Skamania Homeowners Association can impound water behind the dam to create a recreational lake (see Figure 17).

Figure 17: Duncan Creek Dam

Figure 18: View Upstream of the Duncan Creek Dam

Floodplain Connectivity:

There is a limited amount of low gradient floodplain habitat available within the Bonneville Tributaries Subbasin. Most of the tributaries emerge near their confluence with the Columbia River from steep canyons in the Columbia Gorge. State Route 14, the railroad, and other developments along the Columbia River have reduced or eliminated already limited floodplain habitat in many of these systems.

Most of the lower Gibbons Creek floodplain habitat has been disconnected from the stream. Historically, Gibbons Creek flowed into Steigerwald Lake, which was part of the Columbia River's floodplain, and then into the Columbia River. Gibbons Creek supported runs of coho salmon, steelhead, and cutthroat trout; in 1962 Washington Department of Fish observed "many" juvenile coho in the lower reaches of Gibbons Creek (Fiscus 1978 as cited in Barndt et al. 2000: unpublished). In 1966, a dike was constructed to isolate and drain this lake and its associated wetlands, and the creek was diverted through a tide gate and pumping station at the Port of Camas-Washougal. If the Columbia River was above 11.5 feet, this tide-gate would close, pumping would begin, and fish could not enter the creek or would have to leave it through the pump (Bicknell 1988 as cited in Barndt et al. 2000: unpublished). Consequently, fish passage into Gibbons Creek was dependent on the levels of the Columbia River during migration periods. Despite this limitation, coho and steelhead were still found in the creek in 1985 (Bicknell 1988 as cited in Barndt et al. 2000: unpublished).

Steigerwald Lake National Wildlife Refuge (SWR), a 967 acre US Fish and Wildlife Service (USFWS) refuge, was purchased as mitigation for the construction of the second powerhouse at Bonneville dam. Primary objectives of the purchase of SWR were to realign lower Gibbons Creek so that it would not flow through the Port, thereby reducing pumping costs, and providing uninhibited fish passage through the refuge to upstream spawning areas. Thus, the federal government, including the USFWS, has spent over $7.5 million in acquiring land, constructing an elevated fish passage channel and a fish ladder at Gibbons Creek's confluence with the Columbia River, and re-routing the creek through these structures to meet the objective of unrestricted fish passage through Steigerwald Refuge. Resumption of unrestricted fish passage occurred in 1992 (Barndt et al. 2000: unpublished).

A water diversion structure is present on Gibbons Creek just below the north boundary of Steigerwald National Wildlife Refuge. This structure diverts Gibbons Creek from its old channel, which flowed into Steigerwald Lake, into the elevated channel that empties into the Columbia River. The structure is designed to pass 70 cfs into the elevated channel, and to force excess water through a screened opening into the old channel and the Steigerwald Lake bed (Barndt et al. 2000: unpublished; Erickson and Tooley 1996).

While this elevated channel alleviated most fish passage problems, most of the lower mile of the creek is completely disconnected from its historic floodplain. A substantial amount of once productive floodplain habitat of Gibbons Creek and the Columbia River has been lost. The surrounding land, below SR 14 including the wildlife refuge and industrial park, is no longer connected to the elevated channel and still drains into the remnant channel.

Campen Creek is still connected to most of its floodplain; however, a substantial amount of this habitat occurs along the golf course. Obviously, most of the habitat complexity that would benefit fish has been lost along the golf course.

Lawton Creek has also experienced some major alterations of its historic floodplain. Below SR 14, the creek runs alongside the dike that was constructed in 1966 to protect the Steigerwald Refuge and industrial areas of Camas and Washougal. SR 14 and the railroad also constrict the channel and floodplain connections. Above SR 14, extensive gravel mining at the Schmidt Rock site has also likely altered floodplain habitat (TAG).

Various other streams in the subbasin have had floodplain habitat altered and/or disconnected from the channel, including:

- A dike runs along Duncan Creek just above Duncan Creek Road (TAG).
- The lower portion of Woodward creek below SR 14 has been diked and channeled along Woodard Creek Road. SR 14 and the railroad tracks also reduce floodplain connections in the lower reaches (TAG; Bryant 1949).
- Sections of lower Hardy Creek have been channelized. TAG members noted that the lower mile of Hardy is incised and disconnected from its floodplain, and that portions of the creek above this area are diked. Greenia Creek and its associated wetlands are disconnected from Hardy Creek by fish screens. There is a major chum restoration project by the USFWS occurring in the lower reaches of Hardy Creek on what is now part a National Wildlife Refuge.
- From Peterson's gravel quarry down to SR 14, Hamilton Creek has been diked and disconnected from its floodplain and floodplain habitat has been filled. The construction of North Bonneville also filled and disconnected historic floodplain. The SR 14 and railroad bridges confine the stream and reduce historic floodplain connections (TAG: Bryant 1949).
- It appears that Greenleaf Slough was at one time an overflow channel for the Columbia River that was disconnected by the construction of Bonneville Dam. Wetlands associated with the hot springs upstream have also been filled.
- A creek to the west of Good Bear Creek was diverted into Good Bear Creek just above SR 14 and its entire floodplain has been lost (TAG).

Tag members also noted that Franz Lake and its associated wetlands likely provide critical floodplain and off-channel rearing habitat for anadromous fish using Indian Mary Creek, as well as other adjacent creeks such as Good Bear.

<u>Bank Stability:</u>

Data on bank stability is lacking for most streams within the Bonneville Tributaries Subbasin. However, the USFS collected stream habitat data between 1994 and 1996 on a number of creeks within the Columbia River Gorge, including bank stability data on Hamilton and Greenleaf Creeks (see Table 38). In 1997, all surveyed reaches along Greenleaf Creek, to RM 3.4, were considered 100% stable. However, TAG members noted that the upper reaches of Greenleaf Creek run through a naturally unstable area, which is part of the huge slide that formed the Bridge of the Gods. This instability is especially apparent near the falls on Greenleaf Creek at approximately RM 1.2.

Hamilton Creek surveys found that bank stability along the upper three reaches of Hamilton Creek was good, and only the reach between RM 0.8 to RM 1.7 had poor bank stability. Some bank instability occurs in lower Hamilton Creek. A recent visual survey on November 3, 2000 found a slide that had clogged most of the stream channel with debris (see Figure 19). Spawning ground surveys during December determined that this debris slide was not a passage barrier (TAG).

Table 38: Bank Stability in Hamilton and Greenleaf Creeks

Stream Name and Reach	Percent Stable Banks	LFA Rating
Hamilton Creek		
Reach 1 (RM 0.0 to 0.8)	86.8 (Fair)	Fair
Reach 2 (RM 0.8 to 1.7)	69.0 (Poor)	Poor
Reach 3 (RM 1.7 to 4.0)	98.2 (Good)	Good
Reach 4 (RM 4.0 to 5.6)	100.0 (Good)	Good
Reach 5 (RM 5.6 to 6.4)	100.0 (Good)	Good
Greenleaf Creek		
Reach 1 (RM 0.0 to 1.1)	100.0 (Good)	Good
Reach 2 (RM 1.1 to 2.8)	100.0 (Good)	Good
Reach 3 (RM 2.8 to 3.4)	100.0 (Good)	Good

From USFS stream survey data 1997 and 1998

Cattle have access to the lower reaches of Lawton Creek where a rock and gravel crossing has been constructed (TAG). TAG members considered the reach below the railroad on Woodward Creek very unstable. Above the railroad, the stream is channelized and diked. Bank stability rated fair to good on Hardy Creek.

Figure 19: Debris flow in lower Hamilton Creek

photo taken November 2000

Width to depth ratios can also be an important indicator of channel instability. According to Rosgen (1996) “high width/depth ratios, beyond the stable range, indicate a channel’s capacity to transport sediment, due to reduced shear stress associated with the reduced mean depths. Moreover, the distribution of shear stress in streams with a high width/depth ratio is greatest in the near-bank region, thus, accelerating bank erosion and adding to the sediment supply. Increased bank erosion causes further aggradation and lateral extension of the channel within its valley.” USFS stream surveys (1994-1997) measured width/depth ratios in Woodward, Duncan, Good Bear, Hardy, Hamilton, and Greenleaf Creeks. The surveys found somewhat high width/depth ratios in all three reaches of Hardy Creek, the lower two reaches of Hamilton Creek, the lower reach of Duncan Creek, and the lower reach of Greenleaf Creek. In all measured reaches of Woodward and Good Bear Creeks width/depth ratios did not exceed 9.5.

Figure 20: Width-to-depth ratios in lower Hamilton Creek

<u>Large Woody Debris (LWD):</u>

LWD is very limited in most stream channels within the subbasin, especially within the lower reaches. The USFS has conducted stream surveys on a number of streams within the Columbia River Gorge including Woodward, Duncan, Good Bear, Hamilton, and Greenleaf Creeks. Table 39 provides the data collected on LWD for these streams. In every stream system the total LWD/mile increased as the surveyors moved upstream.

The Level II Stream Inventory used for these surveys includes a count of all of the large woody debris that is, the root swell or tree bole of a downed or live tree within the bankfull width. The large wood is classified into the following three size groups: small, one foot in diameter twenty five feet from the large end of the log; medium, two feet in diameter fifty feet from the large end; and large, three feet in diameter fifty feet from the large end (U.S. Forest Service 1997, 1998). The medium and large classes provide superior habitat function because they are more stable (Hicks et al. 1991; Bisson et al. 1987).

Using the LFA Habitat Rating Standards (see Appendix B) all surveyed reaches of all the streams have "poor" levels of LWD (0.2 pieces of LWD/meter of stream channel converts to 321.9 pieces per stream mile). Of the surveyed streams, the upper reaches of Duncan Creek contain by far the greatest amount of LWD per mile, and a substantial proportion of the LWD falls in the "large class". The lower reaches of Hamilton and Greenleaf Creeks have extremely minimal LWD levels. However, LFA standards may not apply in the lower reaches of Hamilton Creek, as the channel is generally greater than 15 meters wide.

Similar data on LWD was collected by the USFWS (Barndt et al. 2000: unpublished) on Gibbons Creek and its major tributaries and this data is summarized in Table 40. It is apparent from Table 40 that large and medium sized LWD is lacking in all surveyed streams within the Gibbons Creek basin. Gibbons Creek contains little functional LWD, and landowners often remove what little LWD does collect (TAG). There is no chance for LWD recruitment along most of the lower mile because woody vegetation is actively removed along the elevated channel to maintain the integrity of the geotextile liner of the channel (TAG).

Table 39: Large Woody Debris per mile along anadromous reaches of Columbia Gorge tributaries

Stream Name	Total LWD/Mile (Large & Medium Classes)	Large Class LWD/Mile	Medium Class LWD/Mile	Small Class LWD/Mile	LFA Rating
Woodward Creek					
Reach 1 (to RM 1.6)	23.6	2.5	21.1	24.5	P
Reach 2 (RM 1.6 – 2.8)	12.7	2.3	10.5	18.6	P
Reach 3 (RM 2.8 – 4.2)	41.0	13.4	27.6	58.6	P
Duncan Creek					
Reach 1 (to RM 1.5)	15.4	5.6	9.8	11.9	P
Reach 2 (RM 1.5 – 3.1)	35.5	11.4	24.1	36.8	P
Reach 3 (RM 3.1 – 3.6	201.8	114.2	87.6	179.0	P
Reach 4 (RM 3.6 – 4.3)	-	-	-	-	No Data
Reach 5 (RM 4.3 – 5.5)	174.7	79.4	95.3	145.4	P
Good Bear Creek					
Reach 1 (to RM 0.3)	45.1	0.0	45.1	45.1	P
Reach 2 (RM 0.3 – 0.6)	46.0	11.5	34.5	80.6	P
Hardy Creek					
Reach 1 (to RM 1.4)	3.6	0.7	2.9	3.6	P
Reach 2 (RM. 1.4 – 3.4)	36.6	14.8	21.8	21.3	P
Hamilton Creek					
Reach 1 (to RM 0.8)	0.0	0.0	0.0	3.5	P
Reach 2 (RM 0.8 – 1.7)	2.1	0.0	2.1	9.4	P
Reach 3 (RM 1.7 – 4.0)	7.6	4.2	3.4	11.3	P
Reach 4 (RM 4.0 – 5.6)	11.6	3.0	8.6	19.2	P
Reach 4 (RM 5.6 – 6.4)	34.7	22.7	12.0	79.0	P
Greenleaf Creek					
Reach 1 (to RM 1.1)	0.9	0.0	0.9	14.0	P
Reach 2 (RM 1.1 - 2.8)	5.1	0.5	4.6	10.8	P
Reach 3 (RM 2.8 - 3.4)	31.3	7.8	23.5	74.4	P

USFS survey data from 1994-1998 (from Richard Larson USFS Fisheries Biologist)

Campen Creek runs first through a golf course for approximately ½ mile and then through urbanized sections near the City of Washougal for almost another mile. The stream contains little LWD and the recruitment potential is very limited. Even within the upper reaches (CC3 reach RM 3.34 –RM 4.05), Campen Creek contains no large or medium sized LWD and only a minimal amount of smaller LWD.

Although survey data is unavailable, TAG members familiar with the systems considered LWD levels as "poor" in both Hardy Creek and in Indian Mary Creek.

Table 40: LWD in Gibbons Creek drainage (1997 through 1998)

	Reach locations										
Parameter	**GC1**	**GC2**	**GC3**	**CC1**	**CC2**	**CC3**	**WC1**	**WC2**	**TT1**	**TT2**	**TT3**
Distance surveyed (miles)	2.24	1.62	1.83	1.72	1.62	0.71	0.78	1.60	0.44	0.67	1.26
Large Wood Per Mile											
Large & Medium classes	3.6	9.3	12.6	1.8	8.0	0.0	14.0	6.9	2.3	3.0	14.3
Small class	18.3	34.7	10.4	9.3	17.2	9.9	44.6	30.6	11.4	19.4	12.7
All classes	21.9	44.0	22.9	11.1	25.2	9.9	58.6	37.5	13.7	22.4	27.1

Data from Barndt et al. 2000: unpublished data
Gibbons Creek (GC), Campen Creek (CC), Wooding Creek (WC) and one unnamed tributary, referred to as Third Trib (TT).

Pool Frequency:

The USFS stream surveys in the Columbia Gorge tributaries also measured the percentage of pool and riffle habitat and pools/mile within specific reaches of each stream. Table 41 provides data on pool habitat in surveyed streams along with average channel gradient and the LFA rating for the reach. The percentage of pool habitat is poor within most reaches of most of the surveyed streams (see Table 41). Exceptions with a "good" percentage of pool habitat include both the lower reaches of Hardy Creek, Reach 3 of Duncan Creek, Reach 1 of Hamilton Creek, and Reaches 1 and 3 of Greenleaf Creek. All reaches of Woodward and Good Bear Creeks had an especially low percentage of pool habitat, with a corresponding high percentage of riffle habitat.

Similar stream survey data was collected by the USFWS on Gibbons Creek and its major tributaries. Table 42 shows that pool habitat is also generally lacking in most reaches of the Gibbons Creek drainage. GC1 (Gibbons Creek reach 1) was 2.24 miles long with 65.5% of the habitat comprised of pools, 33.8% riffles and 0.7% side channels. This reach's relatively low pools/mile (18.3) and large pool area (153,541.8) is due to a series of long pools in a low gradient area just upstream of the fish ladder, which provides a route for fish over the dyke into the Columbia River (Barndt et al. 2000: unpublished).

Pool habitat covered 13.4% of GC2 (1.62 miles), with 85.2% of the area riffles and 1.4% side channels. GC3 (1.83 miles) stands out among the reaches surveyed in the basin. It has the highest pool area (35,155.1ft^2) and second deepest residual pool depth (1.30ft) of all of the reaches with pool/riffle habitat type (35.0% pools, 59.2% riffles) (Barndt et al. 2000: unpublished).

Pool habitat within Campen Creek is also "poor" by LFA standards. Of the surveyed reaches CC1 (Campen Creek 1)(1.72 miles) has a relatively high percentage of pool habitat (39.4%) and conversely no side channel habitat. Its pool area of 24,963.4 ft^2 is the second largest of the reaches and its average pool residual depth of 1.32 ft the second largest (excluding GC1 because of its long, low gradient stretch). Only 6.5% of the habitat in CC2 (1.62 miles) consists of pools, and even the pool residual depth is the lowest among the reaches (0.55ft). CC3 (0.71 miles) has no pools, but does have some side channels (2.7%). Riffles compose 97.3% of the habitat in this reach (Barndt et al. 2000: unpublished).

Table 41: Pool habitat data for various Columbia Gorge tributaries

Stream Name	% Pool	% Riffle	Pools/Mile	Ave. Channel Gradient	LFA rating (% pool)
Woodward Creek					
Reach 1 (to RM 1.6)	5.4	79.8	6.8	3	P
Reach 2 (RM 1.6 – 2.8)	7.1	84.9	9.3	2	P
Reach 3 (RM 2.8 – 4.2)	9.5	80.8	15.1	6	P
Duncan Creek					
Reach 1 (to RM 1.5)	12.8	69.5	16.7	3	P
Reach 2 (RM 1.5 – 3.1)	18.7	80.6	19.1	2	P
Reach 3 (RM 3.1 – 3.6)	46.2	50.9	40.0	7	G
Reach 4 (RM 3.6 – 4.3)	No data	No data	No data	No data	No data
Reach 5 (RM 4.3 – 5.5)	16.0	81.9	20.9	2	P
Good Bear Creek					
Reach 1 (to RM 0.3)	11.9	58.4	26.3	3	P
Reach 2 (RM 0.3 – 0.6)	8.7	88.2	23.0	11	P
Hardy Creek					
Reach 1 (to RM 1.4)	93.4	6.6	22.3	No data	G
Reach 2 (RM 1.4 – 3.4)	32.1	56.5	87.0	No data	G
Hamilton Creek					
Reach 1 (to RM 0.8)	55.8	20.8	9.3	1	G
Reach 2 (RM 0.8 – 1.7)	20.3	66.0	13.6	1	P
Reach 3 (RM 1.7 – 4.0)	12.3	84.4	12.6	6	P
Reach 4 (RM 4.0 – 5.6)	14.0	77.4	15.6	7	P
Reach 5 (RM 5.6 – 6.4)	11.9	86.0	8.4	9	P
Greenleaf Creek					
Reach 1 (to RM 1.1)	62.6	31.2	18.4	3	G
Reach 2 (RM 1.1 - 2.8)	5.9	80.76	11.8	4	P
Reach 3 (RM 2.8 - 3.4)	35.6	59.5	23.5	12	G

USFS survey data from 1994-1998 (from Richard Larson USFS Fisheries Biologist)

Wooding Creek also has a minimal amount of pool habitat. Wooding Creek 1(WC1) (0.78 miles) is dominated by riffles, which comprise 87.2% of the habitat, but it also has a relatively high amount of side channels at 4.3% of the habitat. There are 37.0 pools per mile and a residual pool depth of 0.94ft. Total pool area is 2,841 square feet. WC2 (1.60 miles) has the highest percentage of side channels (9.7%) among the reaches. Despite the fact that pools only make up 4.5% of the habitat, they are relatively frequent (31.3 per mile)(Barndt et al. 2000: unpublished).

The first reach of Third Tributary 1 (TT1) (0.44 miles) has only 12.5% pools and 86.3% riffles. Although pools are a small percent of the habitat, they are the most frequent among the reaches (41.2 per mile). Similarly in TT2 (0.67 miles) there are few pools (4.0%) and 83.6% riffles (Barndt et al. 2000: unpublished). TT2 ends at a natural barrier falls.

Table 42: Pool habitat data in Gibbon Creek (1997 through 1998)

	Reach Locations										
Parameter	**GC1**	**GC2**	**GC3**	**CC1**	**CC2**	**CC3**	**WC1**	**WC2**	**TT1**	**TT2**	**TT3**
Distance surveyed (miles)	2.24	1.62	1.83	1.72	1.62	0.71	0.78	1.60	0.44	0.67	1.26
Percent Habitat Area											
Side Channels (%)	0.7	1.4	4.0	0	0.1	2.7	4.3	9.7	0.8	0.0	0
Riffles (%)	33.8	85.2	59.2	60.4	92.2	97.3	87.2	79.9	86.3	83.6	94.9
Pools (%)	65.5	13.4	35.0	39.4	6.5	0.0	8.5	4.5	12.5	4.0	2.0
Pool Quality											
Pools/mile	18.3	28.5	38.2	31.5	28.3	0.0	37.0	31.3	41.2	22.4	18.3
Total Pool Area (ft^2)	153,542	12,936	35,155	24,963	4,170	0.0	2,894	2,841	2,239	1,227	1,009
Average Residual Pool Depth (ft)	2.24	1.24	1.3	1.32	0.55	--	0.94	0.67	0.99	0.75	0.68

Data from Barndt et al. 2000: unpublished data
Gibbons Creek (GC), Campen Creek (CC), Wooding Creek (WC) and one unnamed tributary, referred to as Third Trib (TT).

Data on pool habitat within most other stream systems within the Bonneville Tributaries Subbasin is lacking. TAG members stated that pool frequency fell somewhere in the fair to good range on Hardy Creek. Pool habitat conditions on Lawton and Indian Mary Creeks are unknown.

<u>Side Channel Availability:</u>

Within the Columbia River Gorge the gradients of many stream systems increase quickly within a short distance from the confluence with the Columbia River. The development of side-channel habitat is generally limited to lower gradient areas below SR 14 and the railroad lines. Development and flood protection has eliminated some historic side channel habitat along the lower reaches in a number of these streams (TAG). The percentage of side channel habitat was measured during USFS stream surveys conducted between 1994 and 1998 in specific reaches of five streams within the Columbia River Gorge. Table 43 provides data on side channel habitat available within these Columbia Gorge tributaries. The lower reach of Hamilton Creek has the largest amount of side channel habitat available for spawning and rearing, and all reaches of Hamilton had some side channel habitat available. A minimal amount of side channel habitat also exists within all surveyed reaches of Woodward Creek, the lower reach of Good Bear Creek, Reach 2 of Hardy Creek, and the upper reaches of Greenleaf Creek. Duncan Creek lacks any substantial amount of side channel habitat.

Side channel habitat has been eliminated along the lower mile of Gibbons Creek where the stream has been channelized and elevated (see Table 44). Historically, this area contained a substantial amount of side- and off-channel habitat for use by anadromous fish. Also, stream channelization reduced connection to any historic side channel habitat just upriver from SR 14. The Columbia Land Trust now owns the land just upstream from SR 14, and there is good potential to restore habitat function along this channelized reach by recreating the streams natural meander pattern along with additional side-channel habitat.

Table 43: Side Channel Habitat in five Bonneville Subbasin Tributaries

Stream Name	Side Channel Habitat (percent of wetted habitat area)
Woodward Creek	
Reach 1 (to RM 1.6)	8.4
Reach 2 (RM 1.6 – 2.8)	5.9
Reach 3 (RM 2.8 – 4.2)	6.1
Duncan Creek	
Reach 1 (to RM 1.5)	2.7
Reach 2 (RM 1.5 – 3.1)	0.7
Reach 3 (RM 3.1 – 3.6)	0.0
Reach 4 (RM 3.6 – 4.3)	No data
Reach 5 (RM 4.3 – 5.5)	0.5
Good Bear Creek	
Reach 1 (to RM 0.3)	11.1
Reach 2 (RM 0.3 – 0.6)	0.0
Hardy Creek	
Reach 1 (to RM 1.4)	0.0
Reach 2 (RM 1.4 – 3.4)	10.4
Hamilton Creek	
Reach 1 (to RM 0.8)	21.3
Reach 2 (RM 0.8 – 1.7)	5.0
Reach 3 (RM 1.7 – 4.0)	3.3
Reach 4 (RM 4.0 – 5.6)	8.6
Reach 5 (RM 5.6 – 6.4)	2.2
Greenleaf Creek	
Reach 1 (to RM 1.1)	0.0
Reach 2 (RM 1.1 - 2.8)	10.2
Reach 3 (RM 2.8 - 3.4)	4.9

USFS survey data from 1994-1998 (from Richard Larson USFS Fisheries Biologist)

Data on side channel availability is somewhat limited for the remaining streams within the Bonneville Tributaries Subbasin. Conditions on Lawton Creek are largely unknown; however, portions of the lower reaches appear to have been channelized and diked along the west bank. Hardy Creek has very little side channel habitat available (TAG). Hamilton Springs is an extremely important side-channel, chum-spawning site developed in the lower reaches of Hamilton Creek to enhance the chum salmon runs.

Table 44: Side Channel habitat in Gibbons Creek drainage (1997 through 1998)

	Reach Locations										
Parameter	**GC1**	**GC2**	**GC3**	**CC1**	**CC2**	**CC3**	**WC1**	**WC2**	**TT1**	**TT2**	**TT3**
Distance surveyed (miles)	2.24	1.62	1.83	1.72	1.62	0.71	0.78	1.60	0.44	0.67	1.26
Percent Habitat Area											
Side Channels (%)	0.7	1.4	4.0	0	0.1	2.7	4.3	9.7	0.8	0.0	0

From Barndt et al. 2000: unpublished
Gibbons Creek (GC), Campen Creek (CC), Wooding Creek (WC) and one unnamed tributary, referred to as Third Trib (TT).

Substrate Fines:

Data is available on substrate conditions for Woodward, Duncan, and Good Bear Creeks through surveys conducted by the USFS between 1994 and 1998 (see Table 45). The later USFS stream surveys reports (after 1995) on Hamilton and Greenleaf Creeks did not include data on substrate conditions. The two upper reaches on Woodward Creek are the only reaches encountered in any of the surveyed streams with embedded substrates.

Table 45: Substrate conditions on four Bonneville Subbasin Tributaries

Stream Name	Bed Substrate (Dominant)	Bed Substrate (Subdominant)	Embeddedness
Woodward Creek			
Reach 1 (to RM 1.6)	Gravel	Cobble	No
Reach 2 (RM 1.6 – 2.8)	Gravel	Cobble	Yes
Reach 3 (RM 2.8 – 4.2)	Gravel	Small Boulders (10"-40")	Yes
Duncan Creek			
Reach 1 (to RM 1.5)	Gravel	Cobble	No
Reach 2 (RM 1.5 – 3.1)	Cobble	Small Boulder	No
Reach 3 (RM 3.1 – 3.6)	Bedrock	Cobble	No
Reach 4 (RM 3.6 – 4.3)	N/A	N/A	N/A
Reach 5 (RM 4.3 – 5.5)	Gravel	Gravel	No
Good Bear Creek			
Reach 1 (to RM 0.3)	Gravel	Sand	No
Reach 2 (RM 0.3 – 0.6)	Gravel	Cobble	No

USFS survey data from 1994-1998 (from Richard Larson USFS Fisheries Biologist)

Table 46 displays data on sediment conditions from stream surveys conducted by the USFWS in Gibbons Creek and its major tributaries from 1997 through 1998. These surveys found that a very high percentage of the substrates in the lower reaches of Gibbons Creek (GC1), and the lower and upper reaches of Campen Creek (CC1 and CC3) were fines (see Table 46). Fines dominated substrate composition in GC1 (47.2%), CC1 (52.6%), and CC3 (62.6%). While in other reaches fines ranged from 18.5% to 36.3% (these percentages still places these reaches above the >17% fines considered "poor" by LFA standards). The surveys also found that the upper reaches of Gibbons Creek (GC3) contained the highest percentage of spawning substrates suitable for both smaller salmonids (43.5%) and larger salmonids (27.7%) of all the surveyed reaches. GC2 also had a high percentage of suitable substrates for larger salmonids (Barndt et al. 2000: unpublished).

There are some fine sediment problems within the existing spawning areas of Hardy Creek (TAG). Spawning ground surveys during 2000 in Hardy Creek found an estimated egg-to-smolt survival rate for chum of 0.23. However, preliminary data for the creek show that dissolved oxygen is not a limiting factor in chum redds, even in higher sediment areas (Barndt 2000: personal comm.). USFWS staff suggest that chum are selectively choosing spring fed spawning areas, which alleviates some of the potential problems with fine sediments (Barndt 2000: personal comm.). Estimated egg-to-smolt survival in Hamilton Creek (0.46) was considerably higher than Hardy Creek (Barndt 2000: personal comm.). The USFWS developed an additional chum-spawning channel in the lower reaches of Hardy Creek below the railroad to attract spawners and increase the available spawning habitat.

Table 46: Sediment conditions within the Gibbons Creek drainage (1997 through 1998)

	Reach locations										
Parameter	**GC1**	**GC2**	**GC3**	**CC1**	**CC2**	**CC3**	**WC1**	**WC2**	**TT1**	**TT2**	**TT3**
Distance surveyed (miles)	2.24	1.62	1.83	1.72	1.62	0.71	0.78	1.60	0.44	0.67	1.26
% of Total substrates in Substrate Class											
Sample Size	2	3	3	3	10	3	2	10	2	7	9
Fines (<2mm)	47.2	18.5	20.7	52.6	33.5	62.6	30.3	33.1	36.3	42.2	20.4
Sediments (3-5mm)	2.4	0.9	1.1	0.9	0.9	0.7	2.2	4.1	3.3	2.5	0.9
Percent of substrates suitable for small bodied salmonids (6-64mm)	30.7	38.7	43.5	38.5	35.9	30.5	33.3	36.4	29.4	30.6	38.7
Percent of substrates suitable for large-bodied salmonids (65-128mm)	15.5	24.3	27.7	5.5	16.1	2.7	18.0	12.5	15.4	12.8	20.4
>129 & bedrock	4.4	17.6	7.0	0.6	16.5	3.5	16.3	13.7	15.7	12	19.7

Data from Barndt et al. 2000: unpublished
Gibbons Creek (GC), Campen Creek (CC), Wooding Creek (WC) and one unnamed tributary, referred to as Third Trib (TT).

Specific data on substrate conditions is lacking for other streams within the subbasin. TAG members noted that sediment fines need to be cleaned out of springs on Duncan Creek now that this stream will be accessible to chum salmon again (see Figure 18). Otherwise, good spawning gravel is present in Duncan Creek for chum. According to TAG members, substrates in Greenleaf Creek are in fair to good condition.

Road densities are used as a surrogate measurement of substrate conditions in the LFA habitat rating standards (see Appendix B), and >3 miles of road per square mile with some valley bottom roads falls in the "poor" category. Within the Hamilton Watershed Administrative Unit (WAU), that includes Duncan, Woodward, Hardy, Hamilton, and Greenleaf Creeks, road densities are approximately 2.23 miles of road per square mile (Lunetta et al. 1997)(see Table 47). This road density falls into the "fair" category using the habitat rating standards (see Appendix B), and there is the possibility that road are contributing excessive amounts of fine sediments to stream systems within the WAU. Within the Mt. Zion WAU, including Gibbons, Campen, Lawton, Good Bear, and Archer Creeks, road densities also fall in the fair category with 2.56 miles of road per square mile. Table 47 also shows the miles of stream adjacent roads (roads within 200 feet of anadromous streams) within the WAUs that make up the Bonneville Subbasin. Over 17 miles of stream adjacent roads are contributing fine sediment inputs to streams within the Hamilton Creek WAU.

Table 47: Road densities, stream adjacent roads, and stream crossing in the Bonneville Subbasin

WAU Name	**Road miles outside 200-foot buffer**	**Road miles in 200-foot buffer**	**Percentage of roads in buffer**	**Stream Crossings /Sq. Mile**	**Road Density**
HAMILTON CREEK	156.78	17.05	9.81	4.8	2.228
MT ZION	106.92	9.44	8.11	4.1	2.561

Data from Lewis County GIS 2000

A number of streams within the subbasin have very heavy loads of course sediments deposited where the streams emerge from steep canyons in the Gorge. This is a natural process; however, to some degree land use activities contribute to coarse sediment loads. Lawton Creek, for example, flows through steep canyons of unconsolidated material in the Troutdale Formation and large gravel deposition occurs at the confluence of Lawton Creek and its major tributary where they emerge from steep canyons. Gravel operations used to pull most of this material out of Lawton Creek in this area and starve the lower reaches for spawning gravels (TAG). The operation is no longer removing gravel and the streambed in the area has become braided, especially behind a rock weir that blocks some sediment transport downstream. This area needs assessment to determine what restoration efforts are needed.

There was tremendous bedload movement in Good Bear Creek during the 1996 floods, resulting in a large deposition of coarse sediment below the railroad culvert. A major tributary has also been diverted into Good Bear Creek altering both the hydrology and sediment transport in these streams (TAG).

WDF (1951) describes the lower mile of Hamilton Creek as having a rough bottom strewn with large gravel and boulders. WDF et al. (1993) states that bedload instability has been a problem for chum in Hamilton Creek as has gravel quality, but they also state that rehabilitation work has begun to address some of these problems. TAG members did not consider fine substrates a problem in Hamilton. In fact, TAG members noted that Hamilton Springs, the major chum spawning area on the creek, had sufficient flows (8 cfs to 10 cfs) to keep the spawning gravels fairly free of fine sediments, despite isolation from the flushing flows of the mainstem of Hamilton Creek. TAG members did not consider fine sediments to be a significant problem in Greenleaf Creek. However, sediment inputs may change since commercial forest owners have logged most of the Greenleaf basin in recent years, and several large quarries operate in the basin.

A minimal amount of spawning habitat exists below SR 14 in Indian Mary Creek. TAG members noted a culvert in the lower reaches is likely affecting sediment transport, and that the creek lacks spawning substrates in the lower reaches.

<u>Riparian Conditions:</u>

Map A-11 in Appendix A displays riparian conditions within a 30-meter buffer along all DNR classified 1, 2, or 3 streams within WRIA 28. The forest cover data, from which this map was originally derived, came from 1988 Landsat 5 Thematic Mapper (TM) data and was updated with 1991 and 1993 data (Lunetta et al. 1997). Riparian buffers were rated as good, poor, or unknown, depending upon the type of forest cover category within the 30-meter buffer. Buffers with late- and mid-seral stage forest cover were mapped as "good" riparian habitat and other lands and buffers with early-seral stage forest cover were rated as unknown because of its wide range of coniferous crown cover (from 10 to 70% coniferous crown cover)(data from Lunetta et al. 1997and Lewis County GIS 2000)

Table 48 summarizes the number of miles in each category of riparian condition (Good, Unknown, and Poor) within each WAU of the Bonneville Tributaries Subbasin. Table 49 summarizes the percentage of good, unknown, and poor riparian habitat within each WAU. As Table 49 displays, the largest percentage of riparian habitat within the Mt. Zion WAU (Gibbons, Campen, Lawton, and Good Bear Creeks) falls in the "poor" category, while the largest percentage in the Hamilton WAU (Duncan, Woodward, Hardy, Hamilton, and Greenleaf

Creeks) falls in the "unknown" (or early seral stage) category. There are very few areas within the subbasin where riparian conditions are "good"; these few areas generally occur in the upper reaches above the anadromous zones on most streams (see Map A-11). Along the low gradient reaches with important habitat for anadromous fish, riparian conditions are mostly "poor" or in some cases "unknown".

Table 48: Riparian Conditions Summary for WAUs within the Bonneville Tributaries Subbasin (Miles)

	Riparian Conditions in each Category (in stream miles)			
WAU Name	**Good**	**Unknown**	**Poor**	**Total Miles**
Hamilton	8.2	54.2	19.0	81.4
Mt. Zion	2.0	19.2	28.6	49.8
Subbasin Total	10.2	73.4	47.6	131.2

Adapted from Lunetta et al. 1997 and Lewis County GIS 2000

Table 49: Riparian Conditions Summary for WAUs within the Bonneville Tributaries Subbasin (Percent)

	Percentage of Stream Miles in each Category			
WAU Name	**Good**	**Unknown**	**Poor**	**Total**
Hamilton	10.1%	66.5%	23.4%	100%
Mt. Zion	4.1%	38.6%	57.3%	100%
Subbasin Total (average)	7.1%	52.5%	40.4%	100%

Adapted from Lunetta et al. 1997 and Lewis County GIS 2000

The USFS conducted stream surveys on a number of streams in the Columbia River Gorge area between 1993-1997. The data on riparian conditions for these streams is summarized in Table 50. As Table 50 displays, only 5 out of 18 surveyed reaches had large trees (LT) within the inner (measured to 25 ft. out from ordinary high water) or outer (25 ft. to 100 ft.) riparian zone. Of these 5 reaches, only reach 2 on Greenleaf had any significant percentage of "large trees" in the inner riparian zone. With a few exceptions, the largest percentage of riparian vegetation in most reaches was either in the SP (Pole/Sapling) and/or ST (Small Trees) category. These categories of riparian vegetation cover may provide adequate stream shading in smaller stream systems, but few trees would be large enough to provide functional LWD to stream channels.

Table 51 displays data on canopy density (the amount of the sky blocked by vegetation within the area over the site) from stream surveys conducted by the USFWS in Gibbons Creek and its major tributaries from 1997 through 1998 (Barndt et al. 2000: unpublished). It appears that the riparian canopy along the lower reaches of both Gibbons Creek (CG1) and Campen Creek (CC1) provides the least shading of all surveyed reaches in the drainage. This isn't surprising considering that the lower reach of Gibbons Creek runs through an elevated channel with no riparian shading and the lower reach of Campen Creek flows through the golf course and residential development. The riparian canopy along most of the other reaches provides fairly good shading, especially in the upper reaches of Gibbons Creek mainstem (CG3), in reach 2 of Campen Creek, and in the upper reaches of Wooding Creek (WC2) and Third Tributary (TT2 and TT3).

Table 50: Riparian conditions in 5 Bonneville Subbasin Tributaries

	Floodplain Vegetation						
Stream Name	Zone Width	GF	SS	SP	ST	LT	MT
Woodward Creek	25 ft.	55%	45%	-	-	-	-
Reach 1 (to RM 1.6)	75 ft.	-	-	3%	97%	-	-
Reach 2 (RM 1.6 – 2.8)	25 ft.	36%	-	64%	-	-	-
	75 ft.	-		40%	60%	-	-
Reach 3 (RM 2.8 – 4.2)	25 ft.	-	39%	28%	33%	-	-
	75 ft.	-	-	-	100%	-	-
Duncan Creek	25 ft.	-	12%	17%	71%	-	-
Reach 1 (to RM 1.5)	75 ft.	-	-	-	100%	-	-
Reach 2 (RM 1.5 – 3.1)	25 ft.	-	27%	26%	47%	-	-
	75 ft.	-	-	9%	91%	-	-
Reach 3 (RM 3.1 – 3.6)	25 ft.	-	43%	-	57%	-	-
	75 ft.	-	-	-	100%	-	-
Reach 4 (RM 3.6 – 4.3)	25 ft.	-	-	-	-	-	-
	75 ft.	-	-	-	-	-	-
Reach 5 (RM 4.3 – 5.5)	25 ft.	-	100%	-		-	-
	75 ft.	-	72%	-	28%	-	-
Hardy Creek	80 ft.	11%	3%	-	86%	-	-
Reach 1 (to RM 1.4)	20 ft.	21%	-	-	79%	-	-
Reach 2 (RM 1.4 – 3.4)	80 ft.	-	-	-	100%	-	-
	20 ft.	3%	-	-	57%	40%	-
Good Bear Creek	25 ft.	4%	32%	35%	29%	-	-
Reach 1 (to RM 0.3)	75 ft.	-	20%	39%	41%	-	-
Reach 2 (RM 0.3 – 0.6)	25 ft.	-	49%	47%	4%	-	-
	75 ft.	-	3%	2%	95%	-	-
Hamilton Creek	25 ft.	-	-	-	-	-	-
Reach 1 (to RM 0.8)	75 ft.	63%	-	-	38%	-	-
Reach 2 (RM 0.8 – 1.7)	25 ft.	9%	27%	29%	35%	-	-
	75 ft.	9%	4%	-	56%	31%	-
Reach 3 (RM 1.7 – 4.0)	25 ft.	-	-	-	-	-	-
	75 ft.	-	-	-	83%	17%	-
Reach 4 (RM 4.0 – 5.6)	25 ft.	-	-	2%	98%	-	-
	75 ft.	-	-	-	98%	2%	-
Reach 5 (RM 5.6 – 6.4)	25 ft.	-	-	-		-	-
	75 ft.	-	-	-		-	-
Greenleaf Creek	25 ft.	-	-	38%	62%	-	-
Reach 1 (to RM 1.1)	75 ft.	-	-	-	41%	-	-
Reach 2 (RM 1.1 - 2.8)	25 ft.	-	-	2%	98%	-	-
	75 ft.	-	-	-	**	-	-
Reach 3 (RM 2.8 - 3.4)	25 ft.	-	-	-	58%	42%	-
	75 ft.	-	-	-	38%	62%	-

USFS survey data from 1994-1998 (from Richard Larson USFS Fisheries Biologist)
GF (Grass/Forb); SS (Shrub/Seedlings); SP (Pole/Sapling); ST (Small Trees); LT (Large Trees); MT (Old Growth)
See USFS 1993 Version 7.0 Stream Inventory Handbook Level I and II (page 56) for vegetation cover definitions.

TAG members noted that the riparian zones along the lower reaches of Lawton Creek generally lacked any coniferous cover and that in areas Himalayan blackberries had taken over. Logging has been extensive in the Woodward Creek basin and riparian buffers are largely covered with deciduous trees (TAG). Riparian conditions are also poor along the lower reaches of Hardy

Creek through the Refuge. Above the refuge TAG members rated riparian conditions as "fair" on Hardy Creek.

Table 51: Riparian canopy cover within the Gibbons Creek drainage (1997 through 1998)

	Reach locations										
Parameter	**GC1**	**GC2**	**GC3**	**CC1**	**CC2**	**CC3**	**WC1**	**WC2**	**TT1**	**TT2**	**TT3**
Distance surveyed (miles)	2.24	1.62	1.83	1.72	1.62	0.71	0.78	1.60	0.44	0.67	1.26
Riparian Canopy Density											
% Canopy Density (stan. dev.)	64.9 (31.9)	84.6 (17.7)	96.5 (12.4)	63.5 (43.0)	92.5 (15.1)	88 (20.8)	84.9 (18.0)	93.6 (10.3)	78.9 (25.2)	87.3 (11.0)	96.4 (5.0)

Data from Barndt et al. 2000: unpublished
Gibbons Creek (GC), Campen Creek (CC), Wooding Creek (WC) and one unnamed tributary, referred to as Third Trib (TT).

Water Quality:

In mainstem Gibbons Creek (GC), water temperatures are 2 to 3 degrees higher downstream of Campen Creek (CC) than upstream (Barndt et al. 2000: unpublished). Temperatures exceeded 18.0°C only once during 204 recorded days between April and October 1998 at 6.4km from the confluence with the Columbia River (i.e., at the downstream limit of GC3), whereas temperatures exceeded 18.0°C 37 times in 214 recorded days during the same months at river kilometer 2.34 (i.e., GC1 downstream of CC)(see Table 52).

Of the two tributaries in which thermographs were installed (Wooding and Campen Creeks) Campen Creek (CC) is the warmest, up to four degrees warmer during the summer, exceeding 18.0° C on 85 of 214 recorded days April to October 1998. Wooding Creek, on the other hand, exceeded 18.0°C only twice in 204-recorded days during those months. Third Tributary (TT) has slightly less riparian cover than WC and GC3. It is expected that TT is not a significant contributor to the warming of mainstem Gibbons Creek. In addition to Campen Creek, Gibbons Creek is also warmed on the Steigerwald National Wildlife Refuge as it passes through the elevated channel and downstream in the series of pools that lead up to the fish ladder. Temperatures recorded during 1997 and 1999 support this same pattern (Barndt et al. 2000: unpublished)(see Table 52).

Diurnal fluctuations during the summer of 1998 in Campen Creek are twice as great as in Wooding Creek and twice as great in GC1 as in GC3. Fluctuation followed the same pattern in 1997 and 1999 (Barndt et al. 2000: unpublished).

While Barndt et al. (2000: unpublished) found numerous water temperature excursions beyond 18° C, the highest recorded temperature measured in Gibbons Creek during monthly monitoring between October 1991 and September 1992 was 16° C (Ehinger 1993 as cited in Erickson 1996).

Gibbons Creek is also listed on Ecology's 303d list for fecal coliform exceedances (WDOE 2000). The suspected sources of elevated fecal coliform levels include failing septic systems and agricultural run-off from small farms and livestock operations (Post 2000). According to Post (2000), in relation to other tributaries in the Gibbons Creek watershed, Campen Creek is contributing the greatest proportion of the fecal coliform load. The fecal coliform relative load from Campen Creek during the study period (September 1994 through January 1995) ranged from 51% to roughly 100%.

Table 52: Number of days stream temperature exceeded 18.0°C April through October 1997, 1998, and 1999.

Month:	April	May	June	July	August	September	October	TOTAL
Number days:	**30**	**31**	**30**	**31**	**31**	**30**	**31**	**214**
1997								
GC at confluence w/ CR	0	11	9	28	31	10 (10)		89 (163)
GC on Steigerwald NWR	0	4	3	23	27	14	0	71
GC d.s. of Evergreen Hwy						1 (6)	0	1 (37)
GC u.s. of CC	0	0	0	2	8	0 (25)		10 (178)
GC at Hans Nagel Rd						0 (7)	0	0 (38)
CC in golf course						4 (7)	0	4 (38)
CC at confluence w/ GC	0	8	7	27	31	8	0	81
WC at confluence w/ GC	0 (16)	0 (23)	0	0	2	0	0	2 (192)
1998								
GC at confluence w/ CR								
GC on Steigerwald NWR	0 (21)	0	1	17	15	4	0	36 (205)
GC d.s. of Evergreen Hwy	0	0	1	17	16	4	0	37
GC u.s. of CC								
GC at Hans Nagel Rd	0 (20)	0	0	1	0	0	0	1 (204)
CC in golf course	3	2	7	26	31	15	1	85
Campen Ck. at confluence	3	1	5	26	22	28	1	86
WC at confluence w/ GC	0 (20)	0	0	2	0	0	0	2 (204)
1999								
GC at confluence w/ CR	0	0	3 (24)					
GC on Steigerwald NWR	0	0	6 (24)	20	21	5	0	52 (208)
GC d.s. of Evergreen Hwy	0 (26)	0	4 (24)					
GC u.s. of CC								
GC at Hans Nagel Rd	0	0	0	0 (26)				
CC in golf course	0	1	9 (24)					
Campen Ck. at confluence	7	11	13 (24)					
WC at confluence w/ GC	0	0	2 (24)	1	0	0	0	3 (208)

(number of days during month temperature was recorded, if less than entire month)
[d.s.=downstream of; u.s.=upstream of; a blank means no temperatures were recorded]
Data from Barndt et al. 2000: unpublished.

USFWS monitoring at two different sites on lower Hardy Creek (Barndt 2000: personal comm.) also found elevated water temperatures (>20°C) on a few summer days during 1998 and 1999. Lack of riparian cover and low summer flows likely contribute to these elevated temperatures.

Water quality information is lacking for most of the other stream systems within the subbasin. USFS stream surveys include water temperature data, but the collection of data is limited to one measurement during the survey period. The surveys found individual water temperature readings on the lower reaches of Hamilton and Greenleaf Creeks of 64°F (17.8°C). TAG members were concerned about potential stormwater impacts from the City of North Bonneville on water quality within Hamilton Creek. A reading of 61°F was recorded in the lower reach of Duncan Creek. There is a steady flow of water from springs in Duncan Creek that likely helps reduce summertime water temperatures and increase water quality (TAG). Water quality is also good in Hardy Creek (TAG).

Water Quantity:

Stream systems within the subbasin have no gauging stations for monitoring flow, and specific data on flow conditions within the Bonneville Tributaries subbasin is lacking. Seasonal streamflows in the subbasin follow the same general pattern as precipitation. Since there are no permanent snowpacks, reservoirs, or other impoundments on the streams within the Bonneville Subbasin, stream flow is a direct result of rainfall and groundwater inputs, and flows vary considerably between winter and summer months (Wildrick et al. 1998).

Land development that eliminates hydrologically mature forest cover and undisturbed soil can result in significant changes to stream hydrology and, in turn, to the physical stability of stream channels (Booth 2000; Richter et al. 1996; Chamberlin et al. 1991). The flow regime of developed basins commonly increases in magnitude, duration, and frequency of peak flow and decreases in summer baseflows (Morley 2000; Booth and Jackson 1997). These changes in streamflow patterns can have major impacts on stream ecosystems (Booth 2000, Richter et al. 1996). Table 53 provides data on vegetation cover for each WAU within the subbasin (from Lunetta et al. 1997). Almost 60% of the land cover in the Mt. Zion WAU and over 46% of the land cover in the Hamilton WAU falls in either the “non-forest” and/or “other” category. These two categories cover areas without mature forest cover including urban areas, agriculture and rangelands, cleared forest, and areas with tree/scrub cover. Subsequently, stream systems within these WAUs are considered hydrologically immature and likely experience increased magnitude, duration, and frequency of peak flows and potentially decreased summer baseflows (Morley 2000; Booth and Jackson 1997). Roads and other impervious surfaces are also contributors to increased peak flows and potentially reduced summer flows in the subbasin (Booth 2000; Furniss et al. 1991).

Table 53: Forest Seral Stage/ Land Cover in the Bonneville Tributaries Subbasin (Acres and Percent Total)

WAU Name	*Seral Stage*	*Late-Seral*	*Mid-Seral*	*Early-Seral*	*Water*	*Non-Forest*	*Other*	*Total*
Mt. Zion	**Acres**	0.0	1573	293	4178	6941	8601	*21586*
	Percent	0.0	7.3	1.4	32.2	19.3	39.8	*100.0*
Hamilton	**Acres**	0.0	12880	2329	1892	2862	12999	*32962*
	Percent	0.0	39.1	7.1	5.7	8.7	39.4	*100.0*

From Lunetta et.al. 1997

Map A-13 in Appendix A illustrates the potential peak flow concerns within each Water Administrative Unit (WAU) of WRIA 28 (Lewis County GIS 2000). The screening criteria used to identify WAU’s within the subbasin with the potential for increased peak flows included WAU’s with >3 miles of road per square mile and over 50% hydrologic immaturity based on land cover (hydrologically immature land covers defined as early seral, non forest, other forest, exclusive of snow-ice, sand bars, water). Functioning WAU’s were considered hydrologically mature and had road densities of less than 3.0 miles of road per square mile. Likely Impaired WAU’s were either hydrologically immature or had road densities greater than 3.0 miles of road per square mile. Impaired WAU’s were both hydrologically immature and had road densities >3.0. Both the Bonneville and Mt. Zion WAU’s are considered likely impaired due to hydrologic immaturity. However, road densities fell below the 3.0 miles per square mile criteria.

Low flow problems may be the most significant water quantity issue in the Bonneville subbasin. A number of historical documents note the problems with lack of flow or subsurface flow in many stream systems in this subbasin (Bryant 1949; WDF 1951; WDF 1973; WDF et al. 1993; Caldwell et al. 1999). Both Bryant (1949) and WDF (1973) noted that surface flow at times disappears in the lower reaches of Woodward and Hamilton Creeks. TAG members also reported that these streams consistently have low flow problems during the summer months. WDF (1951) noted that Hardy Creek goes dry in August and September, and Bryant (1949) stated that Duncan Creek is reported to be intermittent in the summer so that small steelhead are trapped in isolated pools. However, flow is perennial in the upper reaches of Duncan Creek (TAG). Greenleaf Creek has considerable wetland influence with good flows year round (TAG).

An instream flow study was conducted for several creeks and rivers in WRIA 28. An Instream Flow Incremental Methodology (IFIM) study was completed for the Washougal River and toe width flows were calculated for the other streams (see Caldwell et al. 1999). Toe width flows (a way of developing relationships between stream flows and fish habitat requirements) were calculated for seven streams within the subbasin (see Table 54) and spot flow measurements were taken within these streams in September, October, and November of 1998. In comparing the optimal toe width flows of Table 54 with spot flow measurements in Table 55, Woodard Creek and Hamilton Creek toe width flows were near 50 percent of optimal for salmon and steelhead rearing conditions on November 3, 1998, and well below optimal for spawning. For the remaining streams listed in Table 54 flows did not approach even 50 percent of optimal for rearing by November 3. These are all rain fed streams with small drainage basins. According to Loranger (2000: letter), if 1998 were a typical runoff year, it would appear that there is not enough streamflow to support a significant salmonid population.

Table 54: Toe-Width Flows for WRIA 28, Salmon/Washougal.

Stream Name	Tributary to	Average Toe Width (feet)	Toe-Width Flow for Fish Spawning and Rearing (cfs)					
			Chinook Spawning	Coho Spawning	Chum Spawning	Steelhead Spawning	Steelhead Rearing	Salmon Rearing
Gibbons Creek (@ Frontage Rd)	Columbia River	19.5	54.1	26.9	54.1	48.6	11.1	10.0
Lawton Creek (@ HWY 14)	Columbia River	18	49.0	24.3	49.0	44.3	9.9	8.9
Duncan Creek (@HWY 14)	Columbia River	16	42.3	20.8	42.3	38.6	8.4	7.5
Woodward Creek (@ Beacon Rock State Park)	Columbia River	27.5	82.9	42.3	82.9	72.4	18.1	16.4
Hardy Creek (@ HWY 14 crossing)	Columbia River	26.3	78.4	39.9	78.4	68.8	17.0	15.4
Hamilton Creek (nr North Bonneville)	Greenleaf Slough to Columbia River	41.5	138.0	72.4	138.0	116.8	32.5	29.7
Greenleaf Creek (@ Cascade Drive)	Greenleaf Slough to Columbia River	21.7	61.8	31.0	61.8	55.0	13.0	11.7

From Caldwell et al. 1999

Table 55: Spot flow measurements for the Bonneville Tributaries Subbasin

WRIA 28 Measured Flows (in cfs)			
Date	**9/3/98**	**10/3/98**	**11/3/98**
Bonneville Tributaries			
Gibbons Creek (@ Frontage Rd crossing)	3.1	2.1	3.6
Lawton Creek (@ HWY 14 crossing)	1.8	2.9	2.8
Duncan Creek (@ HWY 14 crossing)	0.0	0.0	0.0
Woodward Creek (@ Beacon Rock State Park Rd)	2.7	5.2	7.9
Hardy Creek (@ HWY 14 crossing	0.8	2.1	3
Greenleaf Creek (@ Cascade Drive crossing)	1.7	1.87	1.85
Hamilton Creek (nr North Bonneville)			13.3

From Caldwell et al. 1999

The historic mean monthly flows near the mouth of Gibbons Creek for September, November, and January are 3.9 cfs, 35 cfs, and 54 cfs respectively (Post 2000). The 35 cfs average flow near the mouth in November is substantially different than the spot flow measurements of 3.6 cfs taken by Caldwell et al. (1999) in 1998 approximately 2 miles upstream at the frontage road crossing. If flows at the frontage road (RM 2.24) are near the historic mean monthly flows reported by Post (2000) near the mouth of Gibbon Creek, then Gibbons Creek would fully support coho spawning and steelhead and salmon rearing by November in most years. Limited flow data collected just above the diversion structure is available for early November and late October dates in 1988, 1989, 1991, 1994, 1996, and 1998 from the USFWS (Barndt 2000: personal comm.). Flows ranged from between a low of 3.6 cfs on 10/31/89 to a high of 18.5 cfs on 11/7/94. The higher of these flows would support salmon and steelhead rearing, but not fully support salmon and steelhead spawning.

Creation of an artificial, elevated channel for Gibbons Creek has reduced the overall drainage area of the basin and altered the hydrology by excluding connection to all land below SR 14. By design, flow exceeding 70 cfs is also diverted into Gibbons Creek remnant channel (Erickson and Tooley 1996). Washington Department of Ecology (Post 2000) measured flows of 0.9 cfs, 8.3 cfs, and 58 cfs at the mouth of Campen Creek on 9/8/94, 11/9/94, and 1/17/94 respectively.

The operation of Duncan Creek Dam also alters the natural hydrology of Duncan Creek, blocking passage and influencing the aquatic community. Water is impounded behind the dam from June to October to provide a recreational pond for area residents, after which the water is released to facilitate upstream passage for anadromous fish.

Biological Processes:

The Conservation Commission is using the number of stocks meeting escapement goals as a surrogate measurement of nutrient levels within stream systems (see Appendix B). Escapement for most anadromous stocks in the Bonneville Tributaries Subbasin is likely well below historic averages (LCSCI 1998; WDF et al. 1993), and the lack of carcasses contributing nutrients to the systems may be limiting production within the subbasin. Historical information on most stocks is lacking. In 1951, the Washington Department of Fisheries noted a fair survival of runs of silvers, chum, and steelhead that use Hamilton Creek, that a few silver and chum salmon use the lower portions of Gibbons, St Cloud, and Duncan Creeks, and that Woodward Creek supports runs of silver and chum salmon and steelhead.

SASSI (WDF et al. 1993) considered the Bonneville Tributaries stocks of coho salmon as depressed based on a long-term decline. Combined data from spawning surveys on Duncan, Hardy, Hamilton, and Greenleaf Creeks over the last 50 years found an average of 15 fish per mile with a low of one and a high of 185 in 1952 (WDF et al. 1993). SASSI also provides stock condition estimates for Hardy Creek and Hamilton Creek chum salmon, and Hamilton Creek winter steelhead stocks. The stock status of Hamilton Creek chum is also considered depressed, Hamilton Creek winter steelhead is unknown, and Hardy Creek chum salmon is considered healthy. The condition of Hamilton Creek winter steelhead remained in the unknown category for the LCSCI stock status update in 1998.

Overall, chum salmon production has declined drastically from its former abundance in the lower Columbia (WDF et al. 1993; LCSCI 1998). Chum production within Duncan Creek is just one example. Prior to the construction of the Duncan Creek Dam, peak chum returns exceeded several hundred fish (in 1951 the WDF counted 506 chum in the creek). Afterwards, chum counts plummeted to 4 chum in 1970 and to none between 1970-1995 (Manlow 1998: personal comm.).

Low nutrient levels, habitat alterations and non-native introductions influence competitive interactions and ecological processes in the Bonneville Subbasin. Himalayan blackberries, reed canary grass, and other invasive plant species have invaded the riparian areas along many of the lower reaches of these tributaries. The operation of Duncan Creek Dam likely disturbs and alters the aquatic community. The construction of Bonneville Dam altered flood flow connections between Greenleaf Slough and the Columbia, leaving a slough with sluggish flow and warmer waters that may favor salmonid predators (TAG).

The USFWS (Barndt et al. 2000: unpublished) conducted a survey of the aquatic macroinvertebrate community in four locations on Gibbons and Campen Creeks. They collected and processed invertebrates for the Benthic Index of Biotic Integrity (B-IBI)(Karr and Dudley 1981, Karr et al. 1986) calculations in Campen Creek at the golf course and upstream of Q street, and in Gibbons Creek upstream of Hans Nagel road and downstream of Third Tributary confluence with Gibbons Creek. Point measurements of water quality were also taken at these four sites.

Invertebrate community health was determined from samples collected by kick-net from four of the locations at which fish community structure was evaluated and a B-IBI was calculated. The B-IBI is composed of biological attributes or ‘metrics’ chosen to reflect specific and predictable responses of the stream biota to human activities across the landscape.

Ten metrics were used to determine the B-IBI score (Karr 1996 as cited in Barndt et al. 2000: unpublished):

total number of taxa	number of *Ephemeroptera* taxa
number of *Plecoptera* taxa	number of *Tricoptera* taxa
number of long lived taxa	number of intolerant taxa
percent individuals in tolerant taxa	percent of predator individuals
number of clinger taxa	percent dominance (3 taxa)

Scores for each metric are 1, 3, or 5, and are summed to generate a total score between 10 and 50. These scores indicate condition of the stream habitat from which the invertebrates were collected: in general, scores 46-50 represent excellent condition; 38-45, good condition; 28-37, fair conditions; 18-27, poor conditions; and 10-17, very poor conditions (Karr and Chu 1999 as cited in Barndt et al. 2000: unpublished).

The B-IBI scores collected in riffle habitat were excellent in the upper reaches of both Gibbons Creek (GB3) and Campen Creek (CC2). They were "good" in GC2, and they were poor in Campen Creek along the golf course (see Table 56). B-IBI scores for pool habitat rated fair in the surveyed sites on Gibbons Creek and poor for both sites on Campen Creek.

Table 56: Results and score (in parenthesis) benthic index of biological integrity in the Gibbon Creek.

Reach	Location	Riffle Habitat	Pool Habitat
GC2	downstream of TT confluence	good (42)	fair (32)
GC3	upstream of Hans Nagel Rd	excellent (46)	fair (32)
CC1	golf course	poor (24)	poor (20)
CC2	at W street	excellent (47)	good (40)

From Barndt et al. 2000: unpublished

ASSESSMENT OF HABITAT LIMITING FACTORS

The Conservation Commission reviewed several tribal, state, and federal documents that use some type of habitat rating system in order to develop a set of standards to rate salmonid habitat conditions (see Appendix B). The goal was to identify appropriate rating standards for as many types of limiting factors as possible, with an emphasis on those that could be applied to readily available data. Based on the review, it was decided to rate habitat conditions into three categories: Good, Fair, and Poor. For habitat factors that had wide agreement on how to rate habitat condition, the Washington Conservation Commission (WCC) adopted the accepted standard. For parameters that had a range of standards, one or more of them were adopted. Where no standard could be found, a default rating standard was developed, with the expectation that it will be modified or replaced as better data become available.

The habitat condition ratings for Water Resource Inventory Area (WRIA) 28 are presented in Table 57. These ratings are not intended for use as thresholds for regulatory purposes, but as a coarse screen to identify the most significant limiting factors in WRIA 28. They also will hopefully provide a level a consistency between WRIAs that allows habitat conditions to be compared across the state. However, for many habitat factors, there may not be sufficient data available to use a rating standard or there may be data on habitat parameters where no rating standard is provided. For these factors, the professional judgment of the TAG was used to assign the appropriate ratings.

The Technical Advisory Group (TAG) for WRIA 28 developed Table 57 using the habitat rating standards in Appendix B as a guide. The information for Table 57 came from both published and unpublished studies, and the personal and professional experiences of TAG members. Within some subbasins, both personal experience and quantitative data was lacking. These areas are identified with a ND (no data) designation. Following Table 57 are recommendations from the TAG for addressing habitat limiting factors in each subbasin (the Lake River, Washougal River, and Bonneville Tributaries Subbasins). These recommendations were not prioritized by the TAG. TAG members felt that prioritization would require the further development of a standardized methodology that could be applied within as well as across basins.

Table 57: Identified habitat limiting factors for freshwater streams of WRIA 28

Stream Name	WRIA Index	Fish Passage	Floodplain Connect-ivity	Bank Stability	Large Woody Debris	Pool Ratio and Pools/Mile	Side Channels	Substrate Fines	Riparian Conditions	Water Quality	Water Quantity	Biological Processes
Lake River Subbasin												
Lake River	**280020**	**G**[2]	**P**[2]	**G**[2]	**P**[2]	**G**[2]	**P**[2]	**N/A**	**N/A**	**P**[1]	**G**[2]	**P**[2]
Whipple Creek	**280038**	**P**[1]	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[1]
Packard Creek	**280041**	**P**[2]	**ND**	**ND**	**P**[2]	**ND**	**ND**	**F**[2]	**F**[2]	**ND**	**ND**	**P**[2]
Salmon Creek Mouth to RM 6.2	**280059**	**G**[2]	**P**[2]	**F**[2]	**P**[2]	**F**[2]	**P**[2]	**G**[2]	**P**[2]			
Salmon Creek RM 6.2 – 19.3	**280059**	**F**[2]	**F**[2]	**P**[2]	**P**[1]	**P**[1]	**F**[2]	**P**[1]	**P**[1]	**P**[1]	**P**[2]	**P**[1]
Mill Creek	**280079**	**P**[2]	**P**[1]	**P**[1]	**P**[2]	**P**[2]	**ND**	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]
Curtin Creek	**280085**	**F**[2]	**P**[1]	**P**[2]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**F**[2]	**P**[1]
Woodin Creek	**280089**	**P**[1]	**P**[1]	**G**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**F**[2]	**P**[1]
Morgan Creek	**280093**	**P**[2]	**P**[2]	**P**[2]	**P**[1]	**P**[1]	**ND**	**F**[2]	**P**[1]	**P**[2]	**P**[1]	**P**[1]
Mud Creek	**280094**	**F**[2]	**P**[2]	**P**[2]	**P**[1]	**ND**	**ND**	**F**[2]	**P**[1]	**ND**	**P**[2]	**P**[1]
Baker Creek	**–**	**P**[1]	**P**[2]	**ND**	**P**[2]	**P**[2]	**ND**	**F**[2]	**P**[1]	**ND**	**P**[2]	**P**[1]
Salmon Creek RM 19.3 - 38.5	**260059**	**G**[2]	**NA**	**P**[2]	**P**[1]	**F**[1]	**P**[2]	**P**[2]	**P**[1]	**ND**	**ND**	**P**[1]
Rock Creek	**280105**	**F**[2]	**NA**	**F**[2]	**P**[1]	**P**[1]	**ND**	**F**[2]	**F**[2]	**P**[2]	**F**[2]	**P**[1]
Burnt Bridge Creek	**280143**	**P**[1]	**P**[1]	**F**[2]	**P**[2]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]
Vancouver Lake	**--**	**ND**	**P**[1]	**ND**	**P**[2]	**NA**	**NA**	**NA**	**P**[1]	**P**[1]	**ND**	**P**[1]
Columbia Slope Tribs	**--**	**ND**	**NA**	**ND**	**P**[2]	**ND**	**ND**	**ND**	**P**[2]	**P**[2]	**P**[1]	**P**[2]
Washougal River Subbasin												
Camas Slough	**280154**	**G**[2]	**P**[2]	**G**[2]	**P**[2]	**NA**	**P**[2]	**P**[2]	**P**[1]	**P**[2]	**P**[2]	**P**[1]
Washougal River Mouth to RM 5.6	**280159**	**G**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**ND**	**P**[1]	**P**[2]	**P**[2]	**P**[1]
Lacamas Creek	**280160**	**P**[1]	**ND**	**G**[2]	**P**[2]	**ND**	**ND**	**P**[2]	**G**[2]	**P**[1]	**P**[1]	**P**[1]
Little Washougal	**280204**	**G**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[1]	**P**[2]	**P**[2]	**P**[1]
Boulder Creek	**280213**	**F**[2]	**ND**	**F**[2]	**P**[2]	**P**[2]	**P**[2]	**F**[2]	**F**[2]	**G**[2]	**P**[2]	**P**[1]
EF Little Washougal	**280159**	**G**[2]	**G**[2]	**G**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[1]	**G**[2]	**G**[2]	**P**[1]
Jones Creek	**280218**	**P**[1]	**ND**	**F**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[1]	**P**[2]	**P**[2]	**P**[1]
Washougal River RM 5.6 – RM 14.5	**280159**	**G**[1]	**P**[2]	**F**[2]	**P**[2]	**P**[2]	**P**[2]	**ND**	**P**[1]	**P**[1]	**P**[2]	**P**[1]
Cougar Creek	**280225**	**P**[1]	**ND**	**ND**	**ND**	**ND**	**ND**	**P**[2]	**P**[1]	**ND**	**ND**	**P**[1]
Winkler Creek	**280229**	**P**[1]	**ND**	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[2]	**P**[1]	**P**[2]	**G**[2]	**P**[1]
WF Washougal	**280232**	**P**[1]	**NA**	**F**[2]	**P**[2]	**ND**	**P**[2]	**ND**	**F**[2]	**P**[2]	**P**[1]	**P**[2]

Stream Name	WRIA Index	Fish Passage	Floodplain Connect-ivity	Bank Stability	Large Woody Debris	Pool Ratio and Pools/Mile	Side Channels	Substrate Fines	Riparian Conditions	Water Quality	Water Quantity	Biological Processes
Wild Boy Creek	**280235**	**P**[2]	**NA**	**G**[2]	**F**[2]	**F**[2]	*ND*	**P**[2]	**F**[2]	**ND**	**P**[2]	**P**[1]
Texas Creek	**280237**	**G**[2]	**NA**	**G**[2]	**P**[2]	**P**[2]	**ND**	**G**[2]	**P**[2]	**ND**	**P**[2]	**P**[1]
Hagen Creek	**280242**	**G**[2]	**NA**	**ND**	**ND**	**ND**	**ND**	**ND**	**G**[1]	**ND**	**ND**	**P**[1]
Washougal River RM 14.4 – Headwaters	**280159**	**G**[2]	**P**[2]	**G**[2]	**ND**	**ND**	**ND**	**ND**	**F**[1]	**P**[1]	**G**[2]	**P**[1]
Dugan Creek	**280250**	**P**[2]	**P**[2]	**F**[2]	**F**[2]	**ND**	**ND**	**P**[2]	**F**[2]	**F**[1]	**G**[2]	**P**[1]
Stebbins Creek	**280254**	**G**[2]	**NA**	**ND**	**P**[2]	**ND**	**ND**	**ND**	**P**[2]	**ND**	**ND**	**P**[1]
Timber Creek	**280258**	**P**[2]	**NA**	**F**[2]	**P**[2]	**P**[2]	**F**[2]	**ND**	**F**[2]	**G**[2]	**G**[2]	**P**[1]
Silver Creek	**280261**	**P**[2]	**NA**	**ND**	**ND**	**ND**	**ND**	**ND**	**F**[1]	**ND**	**ND**	**P**[1]
Prospector Creek	**280263**	**G**[2]	**NA**	**ND**	**ND**	**ND**	**ND**	**ND**	**P**[2]	**ND**	**ND**	**P**[1]
Meander Creek	**280267**	**P**[2]	**NA**	**G**[2]	**P**[2]	**P**[2]	**ND**	**ND**	**F**[1]	**G**[2]	**G**[2]	**P**[1]
Grouse Creek	**280268**	**G**[2]	**NA**	**ND**	**ND**	**ND**	**ND**	**ND**	**F**[1]	**ND**	**ND**	**P**[1]
Lookout Creek	**280269**	**G**[2]	**NA**	**ND**	**ND**	**ND**	**ND**	**ND**	**P**[1]	**ND**	**ND**	**P**[1]
Bear Creek	**280270**	**G**[2]	**NA**	**ND**	**ND**	**ND**	**ND**	**ND**	**P**[1]	**ND**	**ND**	**P**[1]
Bonneville Tributaries Subbasin												
Gibbons Creek	**280276**	**P**[1]	**P**[1]	**ND**	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**F**[1]
Campen Creek	**280277**	**P**[1]	**P**[2]	**ND**	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]
Wooding Creek	**280280**	**G**[1]	**ND**	**ND**	**P**[1]	**P**[1]	**G**[1]	**P**[1]	**P**[1]	**F**[1]	**P**[1]	**P**[1]
Third Tributary	**280281**	**P**[1]	**ND**	**ND**	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**P**[1]	**F**[1]	**P**[1]	**P**[1]
Lawton Creek	**290288**	**P**[2]	**P**[2]	**ND**	**P**[2]	**P**[2]	**ND**	**ND**	**P**[1]	**ND**	**ND**	**P**[1]
Archer Creek	**280294**	**ND**	**P**[2]	**ND**	**P**[2]	**ND**	**ND**	**ND**	**P**[1]	**ND**	**ND**	**P**[1]
Goodbear Creek	**280295**	**ND**	**P**[2]	**ND**	**P**[1]	**P**[1]	**G**[1]	**G**[1]	**P**[1]	**ND**	**ND**	**P**[1]
Indian Mary Creek	**NA**	**F**[2]	**P**[2]	**ND**	**ND**	**ND**	**ND**	**ND**	**F**[2]	**G**[2]	**ND**	**P**[1]
Duncan Creek	**280296**	**F**[2]	**P**[2]	**G**[2]	**P**[1]	**P**[1]	**P**[1]	**F**[1]	**P**[1]	**G**[1]	**F**[1]	**P**[1]
Woodward Creek	**280298**	**F**[2]	**P**[2]	**P**[2]	**P**[1]	**P**[1]	**F**[1]	**F**[1]	**P**[1]	**ND**	**P**[1]	**P**[1]
Hardy Creek	**280302**	**P**[2]	**P**[2]	**F**[2]	**P**[1]	**F**[2]	**P**[1]	**F**[1]	**P**[1]	**G**[2]	**P**[1]	**P**[1]
Hamilton Creek	**280303**	**F**[2]	**P**[2]	**F**[2]	**P**[1]	**P**[1]	**G**[1]	**F**[1]	**P**[1]	**ND**	**P**[1]	**P**[1]
Greenleaf Creek	**280304**	**G**[2]	**P**[2]	**G**[2]	**P**[1]	**G**[1]	**P**[1]	**G**[1]	**F**[1]	**ND**	**G**[1]	**P**[1]

P = "Poor" as defined in Appendix B (Salmonid Habitat Condition Rating Standards)
F = "Fair" as defined in Appendix B (Salmonid Habitat Condition Rating Standards)
G = "Good" as defined in Appendix B (Salmonid Habitat Condition Rating Standards)
ND = No data. These habitat conditions need additional research to determine the condition of the habitat.

NA = Not applicable to this area.
1 = Literature source and/or stream survey data.
2 = Technical Advisory Group (TAG) assessment of habitat conditions.

General Recommendations for WRIA 28

There were a number of recommendations that were not specific to individual subbasins and that apply across the entire WRIA including:

- Various land uses practices have negative impacts on habitat conditions for salmonids. If these impacts continue at the existing rate in many of the subbasins of WRIA 28, habitat degradation will outstrip any possible restoration strategy. Critical areas ordinances need to be developed and/or updated to ensure protection of critical habitat for threatened and endangered salmonids. TAG members suggested that jurisdictions following the Municipal, Residential, Commercial, and Industrial Development and Redevelopment Guidelines proposed in the NMFS 4d rule for steelhead would help protect "properly functioning conditions" (PFCs) in the streams of WRIA 28.
- In many areas, existing local, state, and federal regulations would normally provide adequate protection of critical habitat; however, enforcement of these regulations is often lax and unequally enforced. Local, state and federal agencies need to enforce all existing regulations that protect salmonid habitat, water quality, and instream flows.
- Assess, repair, and where possible, decommission roads that are contributing chronic sediment to stream systems or that may fail and lead to landslides, especially within areas with road densities above 3.0 miles/square mile.
- Look for creative solutions to stormwater impacts from existing and future development. Where feasible, alter stormwater facilities to reduce direct runoff to streams and increase infiltration. Protect and enhance wetlands and other water recharge areas.
- Almost every stream system within WRIA 28 has inadequate supplies of LWD. Properly designed and implemented LWD supplementation projects can help collect spawning gravels, enhance pool habitat, create habitat diversity and cover for salmonids, and stabilize stream channels. Supplement LWD in areas that can provide short-term benefits to salmonids, and work towards assuring adequate recruitment potential for long-term LWD supplies within stream systems.
- Riparian restoration is needed almost throughout WRIA 28. Many commercial forest lands are recovering from disturbances early in the last century. Other areas have reduced riparian function due to urban and rural development. Protect existing functional riparian habitat and restore those areas that have been degraded by past activities, starting with productive anadromous tributaries.
- The headwaters of most streams within WRIA contain the vast majority of functional habitat. These areas also provide cool, clean water, spawning sediments and woody debris that helps buffer the impacts to salmonids of various downstream land use activities. Focus on protecting these more pristine habitat reaches from additional land-use impacts.
- Elevated water temperatures are a problem in many stream systems within WRIA 28. Poor riparian conditions, low-flow problems, high width-to-depth ratios, and

impounded water all contribute to elevated water temperatures and water quality problems. A comprehensive approach to water quality improvements is needed that addresses all of these contributing factors across the watershed.

- Water withdrawals, for both industrial and domestic uses, reduce instream flows and the habitat available for salmonids. Explore opportunities to protect and augment stream flows in WRIA 28 during low-flow periods (Caldwell et al. 1997).

Lake River Subbasin

Extensive urban and rural development within the subbasin has degraded habitat in many of the stream systems. Stormwater impacts, loss of forest cover, altered riparian corridors, minimal instream habitat diversity, excessive impervious surfaces, high road densities, channelization and streambank hardening, and flood control projects have all contributed to the degradation of habitat conditions. For each of the following habitat categories the Technical Advisory Group (TAG) has developed recommendations for addressing the major habitat limiting factors in the subbasin.

<u>Access:</u>

On Salmon Creek, just downstream from Highway 99 Bridge, the falls created by the headcut from a recent avulsion into gravel ponds may present the most significant barrier to upstream migration in the Lake River Subbasin. However, the severity of the barrier remains unknown. This potential barrier needs additional assessment to determine what, if any, species are affected by the falls, and if additional problems will occur as a result of the avulsion and subsequent headcut. Other important barriers that need assessment and/or repair include:

- An inoperable fish passage structure on Baker Creek at 164th Circle blocks all passage to approximately 1 mile of upstream habitat. This blockage needs immediate repair, and a survey should be conducted of all downstream passage barriers.
- A survey of potential fish passage issues is needed in Morgan Creek and its tributaries. Possible barriers occur on Morgan Creek above 179th Street where there are private culverts and a number of farming activities that might inhibit passage. Fish passage is likely impaired, especially at low flows, below 182nd Avenue, where the creek runs across cattle pastures in undefined channels.
- In Mud Creek (a Morgan Creek tributary) below 182nd Avenue, low flows and undefined channels also likely inhibit fish passage (TAG). According to Gordon Franklin (2000: personal comm.) reports from the late 1980's suggest that there is also a possible culvert blockage where Mud Creek crosses 182nd Avenue
- A survey of passage barriers is also needed within the Burnt Bridge Creek watershed. Potential barriers that were identified included a series of concrete flumes with steps between Hazel Dell Avenue and I-5, and culverts within the Royal Oaks golf course.
- The flushing canal into Vancouver Lake may affect passage into and/or from the Columbia River to the Lake. This potential barrier could affect juveniles migrating downstream from upstream habitats in the Columbia as well as the local fish migrating into and out of off-channel habitats associated with the lake.

- Culvert blockages on the upper end of Whipple Creek, near 149th Street and on Packard Creek under 179th Street need assessment to determine the amount and quality of habitat lost to anadromous fish. There may be as much as 1.5 miles of available habitat above these blockages, but an assessment of barrier severity and potential habitat quality above the blockages would be appropriate before prioritizing repair. Blockages upstream on Whipple Creek at I-5 and at N. E Union Road also need assessment and repair.
- Passage issues need assessment on the Columbia Slope tributaries. The recent discovery of chum spawning sites in the mainstem Columbia adjacent to the Vancouver shoreline increased the need to assess the importance of these spring fed areas to chum populations in the lower Columbia. Small spring-fed streams along the Columbia Slope may provide additional spawning habitat for this listed species.

Floodplain Connectivity:

Floodplain connections have been substantially altered in many of the stream systems within the Subbasin. Vancouver Lake and the surrounding series of sloughs and wetlands likely provided excellent rearing habitat for salmonids within the subbasin as well as juveniles from upstream habitats. Most of this area has been disconnected from the Columbia by diking and dredge spoils. Instead of providing critical low gradient rearing habitat with substantial habitat diversity, areas like Lake River now only provide a migration corridor with poor habitat conditions and numerous predators.

Roads, railroads, dikes, and other channel alterations have also severed floodplain connections in the lower reaches of Salmon Creek, Burnt Bridge Creek, and Whipple Creek. Recommendations for addressing floodplain connectivity include:

- From an analysis of stream habitat and redd surveys Wille (1989) determined that the potential spawning capacity within the Salmon Creek watershed is much larger than the actual rearing capacity. Restore connections to historic wetlands and side channels within Salmon Creek's floodplain below I-5 to provide additional low gradient rearing habitat.
- Good sites to restore historic floodplain and side-channel habitat occur between 72nd and 182nd Avenues on Salmon Creek. Look for opportunities to approach landowners with project proposals in this area.
- Connections to wetlands in upper Mill Creek have been altered by channelization and channel incision. Maintaining and potentially reconnecting these wetlands to Mill Creek would provide important low gradient rearing habitat and help increase flood capacity within the basin.
- Extensive channelization and dredging of Burnt Bridge Creek has eliminated connection to almost the entire floodplain. Look for opportunities to reconnect floodplains and wetland habitats to the stream. Wetland and floodplain restoration work in Meadow Brook Marsh provides a good example of the potential benefits to be gained for water quality and aquatic health.

Streambed Sediment Conditions:

Most stream systems within the subbasin receive excessive inputs of fine sediment. As Table 57 shows, almost every stream in the subbasin was rated as having poor, or at best fair substrate fines conditions. Stormwater, high road densities, and other related impacts from urbanization, agricultural activities, and the loss of riparian vegetation all contribute to sediment problems within the subbasin. Various stream channels within the subbasin, including Whipple Creek, Burnt Bridge Creek, Curtin Creek, and the upper reaches of Mill Creek are largely silt covered with only minimal amounts of spawning substrates. Recommendations to address sediment conditions include:

- Educate landowners regarding the potential impacts of various land use activities that contribute sediment to stream channels.
- Fence cattle out of streams and restore riparian corridors to reduce erosion. Areas to concentrate on include Mill, Woodin, Morgan, Mud, Baker, Rock, upper Salmon, and Whipple Creeks.
- Protect and restore wetland habitat within the subbasin, especially within the Mill Creek, Curtin Creek, and Burnt Bridge Creek watersheds.
- Reduce stormwater impacts by reducing impervious surfaces and creating additional storage capacity where runoff from roads and developments can infiltrate and drop fine sediment loads. Focus stormwater reduction efforts first in the mid-Salmon Creek basin (from I-5 to 182nd Avenue). The potential still exists in this area to control and eventually reduce stormwater impacts. More restrictive and protective development regulations will hopefully protect the upper salmon Creek watershed from the worst effects of future urbanization, and work within the highly urbanized lower watershed would be extremely expensive and difficult.

Channel Conditions:

Almost throughout the subbasin, functioning Large Woody Debris (LWD) is scarce or absent. Consequently, pool habitat, spawning gravels, and habitat diversity are also scarce. Look for opportunities to enhance pool habitat, spawning habitat, and general habitat diversity by supplementing LWD. Areas to first focus LWD supplementation in the Lake River Subbasin include the upper reaches of Salmon Creek, and Rock Creek where a majority of the quality spawning and rearing habitat in the subbasin occurs.

Supplementation of LWD will benefit instream habitat in the short-term; however, long-term LWD recruitment is needed to maintain the benefits. Protect existing riparian vegetation (preferably conifers) that will eventually provide future LWD recruitment, and work towards restoring areas lacking mature riparian vegetation.

Channel conditions are negatively impacted in many areas where livestock have access to stream and riparian corridors. Most of these problems occur in the Salmon Creek and Whipple Creek watersheds. Efforts by Clark Public Utilities (CPU) to educate landowners within the Salmon Creek watershed and to provide support for fencing and riparian restoration have been extremely successful. During 1999, CPU fenced 16,880 along streams in the Salmon Creek and East Fork Lewis basins (Pacific Groundwater Group 1999). However, there are still areas where landowners need to prevent livestock access to stream corridors, provide alternative water sources, and restore riparian vegetation including:

- Along Mill Creek, livestock access and riparian clearing has reduced streambank stability. CPU has fenced some of the problem areas but there is still a need to fence livestock out of the stream between 199th and 219th Streets (TAG).
- Cattle access in lower end of Morgan Creek, and along the south side of 174th Street has reduced bank stability.
- Mud Creek, below 182nd Ave, runs mainly through pasture and agricultural lands where cattle have access to the stream.
- On Rock Creek at Bridge 266 (Allworth Road crossing) there are some bank stability issues that need attention.

Other areas where bank instability likely presents problems include Whipple Creek just downstream and as far as one mile upstream of Bridge 11 on 179th Street (TAG), and on Salmon Creek, between I-5 and 182nd Avenue just north of Pleasant Valley School, there is a high bank eroding into the creek along an 800-900 foot long stretch (TAG). These areas need assessment and the appropriate treatment.

Channel conditions are likely degraded in the lower reaches of Burnt Bridge Creek and some Columbia Slope tributaries where springs could potentially provide critical spawning habitat for listed stocks of chum salmon. Look for opportunities within these spring-fed areas to enhance channel conditions and potential spawning habitat for chum.

<u>Riparian Conditions:</u>

Riparian conditions are poor throughout the Lake River Subbasin and riparian restoration is needed along almost all streams. Some recommendations for addressing riparian conditions include:

- Only a few areas within the subbasin have fairly high quality riparian habitat. In general these occur in the upper reaches of Salmon Creek, Rock Creek, and Morgan Creek. Protection of this functional riparian habitat should receive the highest priority.
- Replant degraded riparian corridors to help increase bank stability, provide shade and reduce water temperatures, reduce fine sediment delivery to streams, filter pollutants, and provide a future supply of LWD. Focus riparian restoration efforts on the headwaters of Salmon Creek and Rock Creek where some of the best quality spawning and rearing habitat still occurs.
- Continue the work begun by Clark Public Utilities (CPU) to identify potential riparian restoration projects, educate landowners, and provide support for restoration efforts. CPU planted more than 231,000 plants within the Salmon Creek watershed in 1999 (Pacific Groundwater Group 1999).
- Vancouver/Clark Parks Department owns and manages most of the floodplain habitat along lower Salmon Creek between I-5 and the 36th Street Bridge. This property has been developed and primarily managed for general park uses and trail corridors and large sections of the riparian corridors lack any significant tree cover. Riparian

restoration and controlled access to the stream would benefit all salmonids using this area as either a migration corridor or for rearing habitat.

Water Quality:

Serious water quality problems plague most streams within the subbasin. All streams within the Lake River Subbasin that were identified in Table 57 received a “poor” rating or the water quality condition was unknown. Elevated water temperatures are a serious concern in many areas of the subbasin. These problems are likely related to a variety of problems including poor riparian conditions, low flow problems, stormwater and road related issues, impoundments, and impervious surfaces.

Various state and local agencies are developing plans for addressing water quality problems within the Salmon Creek watershed including:

- Washington Department of Ecology is working on the development of a TMDL for Salmon Creek,
- Clark Public Utilities is developing a water resource management plan for the watershed,
- Clark County is in the process of developing a stormwater management plan for the watershed,
- Southwest Washington Health District has developed a plan to identify failing septic tank drainfields systems in the watershed,
- Clark Conservation District works closely with Ecology, and the Natural Resource Conservation Service to provide education and technical assistance to landowners in the watershed.

These activities have focused a considerable amount of attention on the water quality issues within Salmon Creek, and hopefully will eventually lead to water quality improvements within the watershed. However, water quality improvements will likely take a concerted effort over a long time period by various agencies and the entire community. To make major inroads on reducing water temperatures and impacts to salmonids within the subbasin will require a multi-pronged approach that would attempt to address all of these contributing factors including:

- Maintain adequate flows in all streams within the subbasin to buffer water temperatures during summer months.
- Continue efforts of the various agencies that are helping to educate landowners and implement “Best Management Practices” for agricultural activities within the subbasin.
- Protect functional headwater habitat where salmonids can find refuge from elevated water temperatures.
- Assess and, where possible, eliminate impoundments that contribute to elevated water temperatures in the subbasin.
- Protect and restore mature riparian vegetation along all stream corridors within the subbasin.
- Protect and enhance wetlands and spring fed sources of cool water wherever encountered within the subbasin.

- Develop stormwater control facilities within the subbasin to promote infiltration and reduce untreated runoff to streams from roads and other impervious surfaces.
- Restore and enhance pool habitat to provide thermal refuge for salmonids rearing in the subbasin's streams.

TAG members also suggested that water quality improvements in the lower reaches of Salmon Creek would only be realized if substantial improvements in water quality are made in the more urbanized watersheds such as Suds and Cougar Canyon Creeks.

Results of a benthic macroinvertebrate study (Gaddis 1994) found increases of taxa richness, diversity, and community change index as well as a dramatic decline in filter feeding taxa relative to other sites during a two-year study period downstream of the new Meadowbrook stormwater detention facility on Burnt Bridge Creek. He attributed this change to the "greatly expanded diversity of aquatic and riparian habitats" now available within the 6 acres of open water, marsh, and stream habitat provided within the facility. Additional habitat improvements of a similar nature could potentially increase water quality in Burnt Bridge Creek as well as other streams within the subbasin.

Water Quantity:

Both elevated peak flows and low flows are considered limiting factors for salmonids in the Lake River Subbasin (TAG; Caldwell et al. 1997; WDF et al. 1993; Harvester and Wille 1989). Urbanization and other land uses have left almost the entire subbasin hydrologically immature. As such, the streams are likely subjected to increased peak flows that can cause bed and bank scour and channel shifting to the detriment of egg and fry survival (Booth 2000; Richter et al. 1996; Bjornn and Reiser 1991). Similar to water quality problems, there are a number of factors contributing to both elevated and low flow problems within the subbasin. Some broad long-term issues that need to be addressed to decrease elevated peak flows include:

- Restore at least 60% of the subbasin to > 25-year-old timber stands.
- Reduce impervious surfaces and road densities throughout the subbasin.
- Educate landowners and local jurisdictions about techniques that can increase infiltration and reduce direct runoff to streams.
- Encourage land use and development that maintains and enhances forest cover, wetlands, and riparian vegetation.

Low flows are also considered a major limiting factor in the subbasin. Recommendations for addressing major low flow problems are also very broad long-term initiatives that include:

- Reduce impervious surfaces and develop stormwater facilities that will promote groundwater recharge and potentially enhance low summer flows.
- Major water purveyors, such as CPU, should continue to promote conservation and efficient use of groundwater resources (Pacific Groundwater Group 1999).
- Assess all water withdrawals within the subbasin to determine where groundwater resources and stream flows are being depleted.

- Explore opportunities for water reuse where it could supplement instream flows. TAG members noted that water is withdrawn from aquifers within the Salmon Creek watershed for use by the residents of Battle Ground is then piped to the lower reaches of Salmon Creek for wastewater treatment. This wastewater, if treated properly, could potentially be used to increase instream flows in Salmon Creek.
- A number of private water diversions (mostly unauthorized) also alter the hydrology of the basin and contribute to low flow problems in the subbasin (TAG). Survey stream systems within the subbasin for illegal private diversions. Educate landowners about the potential negative impacts of water diversions and enforce existing regulations regarding water diversions.
- Protect and enhance wetlands within the subbasin to help increase infiltration, especially in areas that historically contained extensive wetland habitat, such as Mill Creek, Curtin Creek, and Burnt Bridge Creek.

<u>Biological Processes:</u>

Escapement for most anadromous fish is well below historic numbers and the lack of carcasses contributing nutrients to stream systems may be limiting production. Assess the potential for carcass placement projects within the subbasin to increase nutrient levels and potentially productivity. Additionally, habitat alterations, non-native introductions, and hatchery practices influence competitive interactions and ecological processes in the Lake River Subbasin. Recommendations from the TAG include:

- TAG members expressed concern over the lack of information on warm water predators and their potential impact on salmonids within Lake River. Increase overall habitat diversity and cover within Lake River, Vancouver Lake, and the tidally influenced lower reaches of Salmon Creek and Burnt Bridge Creek to benefit salmonids over native and non-native predators.
- Exotic species like reed canarygrass and Himalayan blackberries have invaded many of the tributaries within the subbasin. The dense canopy and litter layer associated with these species precludes the reestablishment of riparian forest on the higher parcels and wapato and other native wetland plants in the lower elevation parcels (USACE 2000). Look for opportunities to remove these invasive species and reestablish native riparian plants.

Washougal River Subbasin

Past natural and anthropogenic disturbances have had significant impacts on habitat conditions within the subbasin (TAG; McMillan, Bill 2000: letter; WDF 1993; WDW 1990; Parsons date unknown). The Yacolt Burn, forestry practices, splash and hydroelectric dams, road construction, mining, residential and industrial development, water withdrawals, and industrial pollution from paper mills have all altered habitat conditions within the subbasin. Some habitat conditions, such as the water pollution of the lower river from paper mill wastes, have improved considerably over time. However, other habitat conditions have been much slower to recover from past impacts.

Many reaches of the mainstem Washougal and its tributaries still lack adequate structural LWD, spawning gravels, and quality pool habitat. Culverts and dams still block passage to critical and very limited tributary habitat. Stream adjacent roads continue to alter riparian function, alter stream hydrology, and contribute fine sediments to spawning gravels. Water withdrawals continue to limit available spawning and, especially, rearing habitat within the subbasin. Development continues to reduce critical floodplain and riparian functions. The following paragraphs contain recommendations for addressing specific habitat conditions in the Washougal Subbasin.

<u>Access:</u>

Steep gradients and numerous falls limit access to critical tributary spawning and rearing habitat in the Washougal River Subbasin. Artificial passage barriers further limit the habitat available. It is especially important in this subbasin to reopen as much tributary habitat as possible starting with the removal or alteration of some major passage barriers including:

- Probably the most significant passage barrier in the Subbasin is the dam on Wildboy Creek that blocks access to approximately 1.7 miles of good quality habitat, as well as alters sediment transport to downstream reaches. Explore the feasibility of removing this dam.
- The dams on Jones and Boulder Creek block passage into the upper watersheds of these creeks. The amount of available habitat, and the quality of the habitat above these blockages needs assessment to determine the potential benefits gained for anadromous salmonids.
- Water intake structures block adult assess into Vogel Creek to prevent the spread of disease into the hatchery's water supply. Evaluate this practice in light of the plight of endangered species within the subbasin, and if possible open this habitat to native adult salmonids.
- Hatchery weirs and water intake structures also potentially block passage into the upper Washougal, the West Fork Washougal, and wetland complexes adjacent to the Washougal at the salmon hatchery. Assess passage issues at the hatchery complexes and explore opportunities to open access to all historic salmonid habitat in the basin.
- Various small tributaries in the Little Washougal system have passage barriers near their mouths. Even though each individual small stream may have minimal habitat value, historically these streams likely provided important rearing habitat for juveniles. The cumulative impacts of all these barriers may be substantial for salmonids attempting to rear in the basin. Assess and repair the highest priority passage barriers within the Little Washougal stream system.
- Fish passage into some stream systems has been altered over time as a result of channel changes that have occurred after the disturbances in the early 1900's. The potential exists in streams such as Dugan Creek, Prospector/Deer Creeks, and possibly even Canyon Creek to recreate step pool configurations that would enhance or restore access to high-quality tributary habitat.
- The condition of large cemented jams on both Bluebird and Silver Creeks needs assessment, as these jams potentially restrict fish passage, and block the movement of gravel to downstream reaches (Sowinski 2001: letter; McMillan 1997: letter).

Floodplain Connectivity:

Floodplain connections have been lost along portions of the mainstem Washougal and its major tributaries. Various natural and anthropogenic disturbances have disconnected critical floodplain habitat from the river and its tributaries and altered floodplain function. Even today, floodplain development that eliminates critical salmonid habitat continues within the urban areas of Washougal and Camas. Local jurisdictions need to update existing regulations to increase protection of the remaining floodplain habitat within their jurisdictions.

Various opportunities for restoration and enhancement of side channel habitat on the mainstem Washougal River exist below the 3rd Avenue Bridge. TAG members suggested that some of the abandoned gravel pits in the lower Washougal River floodplain could provide valuable floodplain habitat if they were redesigned to conform to more natural floodplain morphology and contained some instream cover. One suggestion was to push some of the dike material to reduce the depth of the ponds and provide additional habitat diversity. Eliminating the dikes could also increase hydrologic connection at a variety of flows and help eliminate potential stranding issues. Also, Fort James opens a gate at the east end of Oak Park Bridge on S.E. 6th Avenue that allows off-road vehicles access to the river to launch boats. The resulting destruction creates erosion, eliminates riparian re-establishment, and negatively impacts floodplain function. Fort James owns a boat ramp that would provide access to the same area, but there isn't any parking area for the ramp. If a parking area was constructed nearby (possibly under nearby BPA lines), then the gate at S.E. 6th Avenue could be permanently closed, the area could be revegetated, and locals would still have a boat access point that was properly constructed.

Other areas where the reconnection of floodplain and side channel habitat could provide benefits include:

- Areas on the north shore of the Washougal just upstream of the 17th Street Bridge have good subsurface flows and adequate room to reconnect and enhance limited floodplain and side-channel habitat in the lower Washougal (TAG).
- School House Creek is an unnamed and unnumbered tributary to the Washougal River that enters the Washougal near the WDFW boat launch above RM 13 just across the Skamania County line. This is a low-gradient, spring-fed stream with good water quality (TAG). Where the creek now crosses Washougal River Road and Malfait Tract Road there is a 100-foot long blocking culvert. Potential exists there to restore some off-channel habitat and forested wetlands by diverting the creek to the west into another stream and through another culvert that is now passable. This restoration would open quality rearing habitat that is now very limited within the Washougal basin.
- Slough Creek, another unnamed, unnumbered tributary to the Washougal River, enters the Washougal above the Vernon Road Bridge (approximately RM 14). It is a spring fed side-channel of the Washougal that provides good rearing and potentially spawning habitat for steelhead, coho, and cutthroat trout.

Streambed Sediment Conditions:

All-terrain vehicle (ATV) use in the Washougal Subbasin contributes a substantial amount of fine sediment to stream systems. The Washington State Department of Natural Resources (DNR) has been attempting to solve this problem for years. Additional resources to educate ATV users about their impacts to stream systems and to enforce closures of critical areas are needed to address this problem. Vegetation management to prevent regrowth along the power line corridors that cross the Washougal Subbasin also invites ATV use and increases the potential for erosion. Management of and access to these power line corridors should be reviewed and updated to reflect the need to protect critical resources in the area.

Numerous stream adjacent roads contribute excessive sediment to stream systems within the Washougal Subbasin. Road related problems are especially apparent in the upper Washougal basin. The subbasin needs a complete assessment of road conditions to develop a prioritized list of road related problems and potential solutions.

Development, farming, and other land use activities also contribute fine sediments to stream systems within the subbasin, especially in the lower Washougal and Little Washougal basins.

- Local jurisdictions and need to review and update erosion and stormwater measures and shoreline regulations to assure protection of aquatic resources from urban and rural development.
- Continue to develop educational programs and incentives programs for landowners to alter various land use activities that negatively impact riparian corridors and increase fine sediment inputs.
- Fence cattle out of stream systems and restore riparian corridors to reduce erosion.
- Assess roads conditions within the watersheds to identify and repair problems areas that route fine sediment inputs directly to streams.

Channel Conditions:

Almost throughout the subbasin functioning LWD is scarce or absent. The lack of LWD, combined with the hydrologic impacts of the Yacolt Burn and subsequent logging, has left many of the stream channels in the Washougal scoured to bedrock and without adequate spawning gravels or pool habitat. For at least one TAG member, the lack of LWD was the most significant limiting factor in the Washougal Subbasin. TAG members agreed that LWD would provide multiple benefits in the basin, and that without it recovery will be slow at best. TAG members felt that properly designed and implemented LWD supplementation would be provide substantial short-term benefits in a number of systems including:

- The Little Washougal system including the mainstem little Washougal, the E.F. Little Washougal, Jones Creek, and Boulder Creek;
- Winkler Creek;
- W.F. Washougal;
- The middle and upper Washougal mainstem;
- Many of the upper Washougal tributaries.

Suggestions for LWD supplementation included the addition of LWD from outside sources to the mainstem Washougal in the form of engineered log jams, or as single logs fed into the upper mainstem (Sowinski 2001: letter). Another LWD supplementation suggestion was to fall individual mature conifers from healthy riparian zones into the tributaries so that they would either provide stable instream LWD in the tributaries or work their way down into the mainstem Washougal.

Supplementation of LWD will benefit instream habitat in the short-term; however, long-term LWD recruitment is needed to maintain the benefits. Protect existing riparian vegetation (preferably conifers) that will eventually provide future LWD recruitment, and work towards restoring areas lacking mature riparian vegetation.

Hydrologic impacts from the Yacolt Burn, land clearing, and LWD removal have also led to generally incised channels with only limited connection to historic side channel habitat in the Washougal River Subbasin. There is potential for some restoration of historic side channel habitat within the lower Washougal River including:

- At the abandoned gravel pits just above RM 1,
- Below the bowling alley near the 3rd Avenue loop (RM 1.5),
- Near the 17th Street Bridge (RM 3),
- Along Hathaway Park at RM 3.5, and
- Along Schmidt's property upstream of the 17th Street Bridge (approximately RM 4).

Diking, riprap, and stream adjacent roads in the Little Washougal basin have also eliminated connection to potential side channel habitat. Look for opportunities to enhance existing side-channel habitat or restore historic connections within the basin. Beavers can play an important role in enhancing and creating additional side-channel habitat for salmonids and, in many systems, their activities should be encouraged (Pess et al. 1999; Swanston 1991).

Riparian Conditions:

Riparian conditions are slowly improving within the Washougal River Subbasin, and unlike the more developed Lake River Subbasin, there are some fairly extensive areas with "good" riparian conditions in the Washougal River Subbasin. These areas are almost all located in the upper reaches of the mainstem Washougal and its tributaries on public or private industrial lands. Protection of these somewhat healthy riparian areas is critical to salmon recovery efforts in the subbasin. Along the more developed areas within the lower reaches, riparian conditions are degraded and protection and restoration is needed.

Recommendations for riparian restoration include:

- Replant degraded riparian corridors to help increase bank stability, provide shade and reduce water temperatures, reduce fine sediment delivery to streams, filter pollutants, and provide a future supply of LWD. Some of the worst riparian habitat degradation has occurred along the lower Little Washougal and Winkler Creek, and the riparian corridors along these streams need immediate attention.

- Protect and/or acquire functional riparian habitat along critical anadromous stream systems, especially in areas where development pressure threatens riparian function and connectivity.
- Numerous stream adjacent roads reduce riparian functions in the upper Washougal. Abandon and/or repair these roads where possible to provide at least a minimal riparian buffer along anadromous streams.

<u>Water Quality:</u>

While some of the major water quality issues in the lower river have been largely resolved over the last few decades, various water quality problems continue to plague the watershed. Water quality problems in Lacamas Creek and Lacamas Lake are persistent problems that can only be addressed over long time periods with major efforts on the part of landowners and regulatory agencies.

Elevated water temperatures are a serious concern in many areas of the Washougal River Subbasin. These problems are likely related to a variety of problems including poor riparian conditions, low flow problems, stormwater and road related issues, impoundments, recreational impacts, and a channel scoured to bedrock. To make major inroads for reducing water temperatures may require a multi-pronged approach that would attempt to address all of these contributing factors including:

- Maintain adequate flows in Jones, Boulder, and Lacamas Creeks to buffer water temperatures during summer months.
- Continue the efforts of Clark County in Lacamas Lake and Lacamas Creek basin to educate landowners and implement "Best Management Practices" for various land use activities. Continued development within this basin also threatens water quality and water quantity within the Lacamas Creek watershed. The cumulative impacts to salmonid habitat from this ongoing development needs to be addressed as Clark County and the City of Camas review development proposals.
- Protect functional headwater habitat where salmonids can find refuge from elevated water temperatures, especially within the upper Washougal, Little Washougal, and North Fork Washougal.
- Assess and, where possible, eliminate impoundments that contribute to elevated water temperatures in the subbasin. TAG members noted that Winkler Creek contained a number of impoundments that likely contribute to elevated water temperatures, and surveys are needed to identify and eliminate them.
- Protect and restore mature riparian vegetation along all stream corridors within the subbasin. Some priority restoration sites include the lower reaches of the Little Washougal and Winkler Creek.
- Protect and enhance forested wetlands and spring fed sources of cool water.
- Develop and enhance pool habitat to provide thermal refuge for salmonids rearing and staging in the subbasin's streams.

Water Quantity:

Both elevated peak flows and low flows are considered limiting factors for salmonids in the Washougal River Subbasin (TAG; Caldwell et al. 1997; WDF 1990). Various disturbances and land uses have left all but the upper reaches of the subbasin hydrologically immature. As such, the streams are likely subjected to increased peak flows that can cause bed and bank scour and channel shifting to the detriment of egg and fry survival (Booth 2000; Richter et al. 1996; Bjornn and Reiser 1991). Recommendations to address elevated peak flows include:

- Maintain more than 60% of the subbasin in at least 25-year-old timber stands.
- Reduce impervious surfaces and road densities throughout the subbasin.
- Educate landowners and local jurisdictions about techniques that can increase infiltration and reduce direct runoff to streams.
- Encourage land use and development that maintains and enhances forest cover, wetlands, and riparian vegetation.

Low flows are also considered a major limiting factor in the subbasin. Recommendations for addressing major low flow problems include:

- Water withdrawals from Jones and Boulder Creeks reduce already low summer streamflow within the Little Washougal watershed. The City of Camas needs to assess the impacts of its water withdrawals on habitat for listed salmonids. They need to look for other sources of water and consider the availability of water in their comprehensive planning process and in the approval process for all additional development and land use decisions.
- Water withdrawals and the existing operational plan for the dam on Round Lake reduce flows into Lacamas Creek to a trickle during the summer months. The present owners of the paper mill need to assess the potential impacts of their water withdrawals, their strategies for operating the dams, and all other activities that potentially impact salmonid habitat.
- Low summer flows, combined with high public use above Dugan Falls, negatively impacts the adult population of summer steelhead through harassing and/or killing of holding fish (McMillan, Bill 2000: letter; WDF 1990). Look for opportunities to reduce these impacts through increased public education and outreach, additional enforcement of existing regulations, and potentially creating sanctuaries for steelhead in critical holding areas within the upper Washougal.
- A number of private water diversions (mostly unauthorized) also alter the hydrology of the basin and contribute to low flow problems in the subbasin (TAG; WDF 1973). Survey stream systems within the subbasin for illegal private diversions starting with Winkler Creek. Educate landowners about the potential negative impacts of water diversions and enforce existing regulations regarding water diversions.

Biological Processes:

Escapement for most anadromous fish is well below historic numbers and the lack of carcasses contributing nutrients to stream systems may be limiting production. Assess the potential for carcass placement projects within the subbasin to increase nutrient levels and potentially productivity. Additionally, habitat alterations, non-native introductions, and hatchery practices influence competitive interactions and ecological processes in the Washougal Subbasin. Recommendations from the TAG include:

- Increase overall habitat diversity within the lower river to benefit salmonids over native and non-native predators.
- There is concern about the impact of hatchery fish on stocks of salmon and steelhead within the subbasin. Hatchery operations need to review and update their plans to protect native stocks of salmon and steelhead. On the North Fork Washougal, TAG members suggested the need for a trap to separate out hatchery fish and reduce interactions between hatchery and wild fish on the spawning grounds.
- Brown trout (non-indigenous) are planted in Lacamas Lake and some make their way down into the Washougal Basin (TAG). Assessment is needed to determine the potential impact from these non-native fish.
- Low summer flows, combined with high public use above Dugan Falls, negatively impacts the adult population of summer steelhead through harassing and/or killing of holding fish (McMillan, Bill 2000: letter; WDF 1990). Look for opportunities to reduce these impacts through increased public education and outreach, additional enforcement of existing regulations, and potentially creating sanctuaries for steelhead in critical holding areas within the upper Washougal.

Bonneville Tributaries Subbasin

A number of the Bonneville Subbasin tributaries fall within the Columbia River Gorge National Scenic area and are protected from future development pressure. However, timber harvests, transportation corridors, passage barriers, and rural development have all contributed to habitat degradation in the subbasin, and smaller communities are rapidly developing. For each of the following habitat categories TAG members developed recommendations for addressing the major habitat limiting factors in the subbasin.

<u>Access:</u>

Most of the streams within this subbasin contain only a limited amount of lower gradient habitat for spawning and rearing of anadromous salmonids, and this limited habitat is located almost completely in the lower reaches. The railroads, State Route (SR) 14, dikes, and other artificial structures have reduced or eliminated access to some of the most productive habitat within the subbasin, as well as reduced the overall quality of that habitat. The Department of Transportation, railroad owners, US Fish and Wildlife Service (USFWS), and local jurisdictions should continue to evaluate the impact of these structures on anadromous fish and look for opportunities to address both passage issues and the restoration of natural hydrology and sediment transport within these streams. Two of only three remaining stocks of chum salmon in the lower Columbia River depend on just a few streams within the subbasin, and protection and enhancement of these streams is critical for recovery of these stocks.

Additional TAG recommendations for addressing access problems within the subbasin include:

- A partial to total barrier on Gibbons Creek at Hans Nagel Road blocks approximately 1.43 miles of the best habitat in the watershed. This culvert and another blocking culvert 200 meters upstream on private land are the most critical barriers to repair, and possibly the most critical limiting factor, in the Gibbons Creek watershed.
- Explore alternatives that would increase the capacity of the diversion channel just downstream from State Route 14 or reduce upstream sediment inputs so that fish are not spilled into adjacent fields and stranded during high flows (TAG).
- The new Duncan Creek Dam and passage facility should reopen an important chum-spawning stream in the lower Columbia. Monitor the utilization of upstream habitats to determine if chum salmon are recolonizing upstream spawning habitat.
- The culverts under the railroad crossing and SR 14 on Hardy Creek block passage to almost a mile of habitat. TAG members noted that this habitat is very steep and contains coarse sediments that are generally unsuitable as spawning substrate.
- Limited low gradient rearing habitat exists in the Bonneville Tributaries Subbasin, and a fish screen blocks access to potentially productive rearing habitat in Greenia Creek, a small tributary of Hardy Creek. This screen is intended to protect western pond turtle populations. Assess the potential to reopen Greenia Creek for salmonids without harming imperiled Western Pond Turtle populations.
- A number of blockages occur on Campen Creek; however, the fish barrier at Q street doesn't really pose a major problem due to lack of spawning and rearing habitat in upstream reaches (Barndt et al. 2000: unpublished).

<u>Floodplain Connectivity:</u>

There is only a limited amount of low gradient floodplain and side-channel habitat available within the Bonneville Tributaries Subbasin. Most of the streams emerge near their confluence with the Columbia River from steep canyons in the Columbia Gorge. State Route 14, the railroad, and other development along the Columbia have reduced or eliminated already limited floodplain habitat in many of these systems. Look for opportunities to increase floodplain habitat availability and quality in the lower reaches of these smaller tributaries.

A significant amount of Columbia River floodplain habitat has been lost in the Steigerwald National Wildlife Refuge area where Gibbons Creek enters the Columbia River. Similar to areas downstream in the Lake River Subbasin, floodplain habitat that was once connected regularly to the Columbia River at higher flows is now disconnected from the river by diking. Actions have been taken to address passage issues on Gibbons Creek; however, floodplain functions remain impaired. While restoring functional floodplain habitat along this reach would likely benefit a number of upstream and local Columbia River salmon and steelhead stocks, it would also require extensive modification of the diking system, stream channels, and overall drainage patterns for these stream systems, and the cost of restoring floodplain function in this area may greatly outweigh the potential benefits. One suggestion for another option would be to increase the capacity of the artificial channel so that it can handle flood flows and natural bedload movement. However, this is may also be an expensive remedy.

The Columbia Land Trust now owns the land adjacent to Gibbons Creek just upstream from SR 14, and there is good potential to restore habitat function along the channelized this reach by recreating the streams natural meander pattern along with additional side-channel habitat.

Other opportunities to increase and/or enhance floodplain habitat include:

- Acquire the property or conservation easements along the lower reaches of Lawton Creek to remove dikes and restore natural meander patterns within the floodplain. Also, assess floodplain conditions within the reaches affected by past gravel mining on Lawton Creek to determine potential restoration strategies.
- Acquire the property on Hamilton Creek between the canyon and SR 14 to remove dikes and allow the channel to move naturally within its floodplain.

<u>Streambed Sediment Conditions:</u>

Fine sediment conditions within Gibbons Creek and its tributaries are "poor" and likely a major limiting factor (TAG; Barndt et al. 2000: unpublished). Recommendations for addressing excessive fine sediments in Gibbons Creek include:

- Restore and protect riparian vegetation along anadromous habitat in the watershed. The upper reaches of Gibbons Creek, above Hans Nagel Road, are the most critical areas to first focus riparian restoration and protection efforts, since this area still contains some of the best habitat within the watershed (Barndt et al. 2000: unpublished).
- Reduce stormwater impacts by reducing impervious surfaces and creating additional storage capacity where runoff from roads and developments can infiltrate and drop fine sediment loads.
- Educate landowners regarding the potential impacts of various land use activities that contribute sediment to stream channels.

Other recommendations to address fine sediment problems within the subbasin include:

- Fine sediments have accumulated in the spring fed areas of Duncan Creek that could provide critical chum spawning habitat. Spawning substrates within the springs need cleaning now that the area is accessible to chum salmon.
- Fine sediment deposition occurs within the Duncan Creek when the dam is closed during the summer months to fill the lake. Monitoring is needed to quantify the potential impacts to chum spawning substrates from the operation of the dam, and to determine if adaptive management strategies are necessary to protect listed species.
- TAG members noted that Hardy Creek is likely receiving excessive inputs of fine sediments; however, USFWS data (Barndt 2000: personal comm.) show that chum are selectively choosing spring fed spawning areas, which alleviates some of the potential problems with fine sediments. Continue to monitor the condition of spawning substrates within Hardy Creek.
- Stream adjacent roads also likely contribute excessive fine sediments to Hardy, Woodward, and lower Duncan Creeks. These roads need assessment and appropriate treatments to reduce fine sediment inputs.

A number of streams within the subbasin also have very heavy loads of course sediments deposited where the streams emerge from steep canyons in the Gorge. To some degree this is a natural process, and to some degree these sediment loads have increased due to land use activities and artificial structures within the subbasin. Subsurface streamflow is often the result of these heavy bedload depositions, and low-flow passage problems often occur during the summer months in Hamilton, Woodward, Hardy, and Good Bear Creeks (TAG; Bryant 1949; WDF 1951; WDF 1973; WDF et al. 1993; Caldwell et al. 1999). Culverts along SR 14 and the railroads exacerbate this natural condition as they can alter or constrict the movement of coarse sediments down through these systems (TAG). Look for opportunities to restore the natural hydrology and movement of sediments through these stream systems.

Sediment transport is also affected by the culvert under the railroad on Indian Mary Creek, resulting in insufficient spawning gravels in the lower reaches (TAG).

<u>Channel Conditions:</u>
Almost throughout the subbasin, functioning Large Woody Debris (LWD) is scarce or absent. Consequently, pool habitat and habitat diversity are also scarce. Since riparian conditions are also generally poor and mature conifers are scarce, LWD recruitment potential is also low within most streams. LWD supplementation may be necessary in areas to enhance pool habitat, spawning habitat, and general habitat diversity in the short-term. For most of the tributaries within the Columbia Gorge habitat is limited to a few miles of low gradient habitat near the mouth and supplementation would provide multiple benefits within these areas. However, the stream channels are subject to extremely high flows and the stability and potential success of any LWD supplementation project should be carefully evaluated before proceeding. The new Hardy Creek Spawning Channel is one area where LWD supplementation would help increase habitat diversity and retain spawning gravels, without the risks found in unmanaged channels.

Supplementation of LWD will benefit instream habitat in the short-term; however, long-term LWD recruitment is needed to maintain the benefits. Protect existing riparian vegetation (preferably conifers) that will eventually provide future LWD recruitment, and work towards restoring areas lacking mature riparian vegetation.

Bank stability problems were noted along the lower reaches of Woodward and Lawton Creeks. TAG members recommended that the stream channels in lower reaches of Woodward and Lawton Creeks need restoration. Cattle need to be excluded from Lawton Creek and a natural channel meander pattern needs to be reestablished. Recreation of a natural channel meander pattern would also benefit habitat within lower Woodward Creek and Gibbons Creek on the Columbia Land Trust's property, where the potential exists to enhance existing habitat and to create additional spawning habitat.

Riparian Conditions:

Riparian conditions are poor along almost every stream within the subbasin, especially along the lower reaches with productive anadromous habitat. Protection of existing mature riparian habitat and restoration of the lower reaches is a high priority within the subbasin. Recommendations for addressing poor riparian conditions include:

- First protect intact riparian habitat along the most productive anadromous tributaries in the subbasin. Intact riparian habitat generally occurs along the upper reaches of most streams within the subbasin, and maintaining this riparian cover will help assure the delivery of cool clear water to downstream reaches.
- Then target riparian restoration efforts along the most productive and/or degraded streams including the lower reaches of Hardy, Hamilton, Lawton, and Woodward Creeks. The lower reaches of Hardy Creek, including the new spawning channel, would especially benefit from riparian plantings. The lower reaches of Lawton Creek need riparian fencing, blackberry removal, and then riparian plantings.
- Reverse the loss of riparian vegetation along Gibbons Creek and its tributaries. This would contribute significantly to a decrease in water temperature and reduce daily fluctuations in temperature (diurnal fluctuations) during the summer months. Reach one of Campen Creek and reach one of Gibbons Creek would most benefit from the replanting of riparian vegetation. Revegetation of these reaches coupled with active protection of those areas which still have shading from intact riparian corridors is probably the single most important way that individual private land owners can protect listed anadromous salmon species (Barndt et al. 2000: unpublished).
- Numerous stream adjacent roads reduce riparian functions along Woodward Creek and Duncan Creek. Explore opportunities to abandon and/or repair these roads to provide at least a minimal riparian buffer along anadromous streams.

Water Quality:

Other than some limited data on Gibbons, Campen, and Hardy Creeks water quality data is lacking within the Bonneville Tributaries Subbasin. Both the USFWS watershed analysis for Gibbons Creek (Barndt et al. 2000: unpublished) and the Gibbons Creek Watershed Fecal Coliform TMDL (Post 2000) found that significant water quality problems occur within the watershed. Recommendations for addressing water quality problems within the Gibbons Creek watershed include:

- Participants in the TMDL planning process that is now underway for the Gibbons Creek watershed will identify sources of non-point pollution that contribute to various water quality problems and work with various local, state, and federal agencies to control some of these non-point pollution sources. With the support of local jurisdictions and the community, this process should provide the best avenue for protecting water quality within the watershed.
- Campen Creek contributed the greatest proportion of fecal coliform load to the watershed in relation to other tributaries, and the lower reaches of Campen Creek also had the warmest water temperatures and the greatest daily fluctuations in temperature of any reach measured within the watershed. Lack of riparian cover along the lower reach of Campen Creek, including the golf course and numerous small residential lots, stormwater impacts, on-site septic systems, and agricultural activities all

contribute to water quality problems in Campen Creek (TAG; Post 2000). It will be important for Clark County and the City of Washougal to establish policies and regulations that will protect and restore riparian canopies along the creek, reduce stormwater impacts, and to play leadership roles in educating and encouraging land owners to protect and enhance native vegetation along streams, and to avoid activities that destabilize banks or alter instream habitat (TAG; Barndt et al. 2000).

- Extensive development is either underway or proposed within the Gibbons Creek watershed. Various state and local agencies need to review development plans to assure protection of water quality that might result from the cumulative impacts of the additional impervious area, road density, and the loss of forest cover.
- Protection and enhancement of headwater riparian corridors in the Gibbons Creek watershed is needed to create sanctuary areas with cool, clear water for salmonids, and to buffer the water quality impacts of downstream development (Barndt et al. 2000).

USFWS monitoring (Barndt 2000: personal comm.) also found elevated water temperatures in two sites on lower Hardy Creek. Lack of riparian cover and low summer flows likely contribute to these elevated temperatures. Restoration of riparian cover should help reduce temperature problems in the lower reaches.

TAG members were also concerned about suspected water quality problems in lower Hamilton Creek, and they recommended that the City of North Bonneville develop a stormwater treatment plan and facilities to protect the water quality in lower Hamilton Creek. Additional riparian cover is also needed along the lower reaches of the creek.

Water Quantity:

Both elevated peak flows and low flows are considered limiting factors for salmonids in the Bonneville Tributaries Subbasin (TAG; Caldwell et al. 1997; WDF et al. 1993). Urbanization, forestry, agriculture, and other land uses have left portions of subbasin hydrologically immature (>60% of the subbasin in at least 25-year-old timber stands). As such, the streams are likely subjected to increased peak flows that can cause bed and bank scour and channel shifting to the detriment of egg and fry survival (Booth 2000; Richter et al. 1996; Bjornn and Reiser 1991). Similar to water quality problems, there are a number of factors contributing to both elevated and low flow problems within the subbasin. Some broad long-term issues that need to be addressed to decrease elevated peak flows include:

- Maintain at least 60% of the subbasin in at least 25-year-old timber stands.
- Reduce impervious surfaces and road densities throughout the subbasin.
- Educate landowners and local jurisdictions about techniques that can increase infiltration and reduce direct runoff to streams.
- Encourage land use and development that maintains and enhances forest cover, wetlands, and riparian vegetation.

Rapid residential development is occurring within the Gibbons Creek watershed, adding to what are already likely high levels of impervious surfaces and loss of forest cover.

The cumulative impacts of additional development will likely lead to further degradation of stream channels and salmonid habitat within this watershed, and local jurisdictions need to address additional degradation when evaluating new development proposals.

The National Scenic Area Act should limit impacts from rapid development within the Columbia Gorge National Scenic Area, except within the small, fast-growing communities such as North Bonneville. In these areas, storm water treatment facilities are needed to minimize stormwater impacts to downstream habitats.

Historically, all streams within the subbasin, especially streams within the Columbia River Gorge, have probably always been subject to low flow during summer months, reducing available habitat for some species. However, chum salmon likely thrived in these stream systems, because these streams don't fully support other species, such as coho and steelhead that rear for at least a year in fresh water. Without these other species present, competition and predation on chum juveniles is reduced. Also, springs, that chum target for spawning, occur frequently in the lower gradient reaches that chum can access. It is especially critical that the springs within the lower reaches of Duncan, Hardy, Hamilton, and other areas that can support chum are protected and enhanced wherever feasible.

Within more urbanized streams, such as Gibbons and Campen Creeks, summer low flows are likely exacerbated by high levels of impervious surfaces, the loss of wetlands and other critical recharge areas, and groundwater withdrawals. Similar to the other subbasins in WRIA 28, the recommendations for addressing major low flow problems are very broad long-term initiatives that include:

- Reduce impervious surfaces and develop stormwater facilities that will promote groundwater recharge and potentially enhance low summer flows.
- Major water purveyors should continue to promote conservation and efficient use of groundwater resources, and look for opportunities for water reuse where it could supplement instream flows.
- Survey stream systems within the watershed for illegal private diversions. Educate landowners about the potential negative impacts of water diversions and enforce existing regulations regarding water diversions.
- Protect and enhance wetlands and other groundwater recharge areas within the subbasin.

The hydrology of Greenleaf Slough, Bass Lake, and Moffett Creek have been substantially altered by the construction of Bonneville Dam. Look for opportunities to provide year-round flows again to these systems.

Biological Processes:

Escapement for most anadromous fish is well below historic numbers and the lack of carcasses contributing nutrients to stream systems may be limiting production. Assess the potential for carcass placement projects within the subbasin to increase nutrient levels and potentially productivity. Additionally, habitat alterations and non-native introductions influence competitive interactions and ecological processes in the Bonneville Tributaries Subbasin. Recommendations from the TAG include:

- Remove reed canary grass from the Duncan Creek springs and promote reestablishment of native plant species.
- Himalayan blackberries, reed canary grass, and other invasive plant species have invaded the riparian areas along many of the lower reaches of these tributaries. Remove blackberries and other invasive plant species from lower Lawton Creek and other affected streams and restore the native plant community.
- The operation of Duncan Creek Dam likely disturbs and alters the aquatic community and plant community. Continue to assess the operation strategies for the dam and reservoir for potential impacts to aquatic health and salmonids, and practice adaptive management.
- The construction of Bonneville Dam altered flood flow connections between Greenleaf Slough and the Columbia, leaving a slough with sluggish flow and warmer waters that may favor salmonid predators (TAG). Look for opportunities to increase flow within Greenleaf Slough.

HABITATS IN NEED OF PROTECTION

Recommendations

The WRIA 28 Technical Advisory Group (TAG) had some difficulty narrowing down specific areas within the various basins that provide habitats in need of protection for a number of reasons. In many areas data on watershed processes, historic and current habitat conditions and alterations, and fish distribution by life history stage is unavailable. Without this data it is difficult to determine what limits salmonid production within freshwater, and therefore areas where protection is most critical. Also, the various species of salmon and steelhead have evolved different life-history traits that tend to maximize the use of all available habitats within a watershed. Almost every part of the watershed provides important habitat for some species during some life-history phase. Lastly, habitat-forming processes (e.g., the rates and delivery of water, sediment, heat, organic materials, nutrients, and other dissolved materials) create the habitat conditions on which salmon rely. Protection and restoration of salmon habitat will require that we increase the scale of our efforts to protect and maintain the natural range of variability for these various processes across entire watershed. The Governor's Salmon Recovery Office has recommended this approach in the draft "Statewide Watershed Assessment Guidance for Salmon," February 2000.

However, there are general areas within each subbasin that provide especially important habitat for the various species. These areas are listed below by subbasin.

<u>Lake River Subbasin</u>
New spawning grounds for chum were recently discovered along the northern Columbia River shoreline near the I-205 Bridge. Numerous spring-fed areas along this reach may provide an important spawning area for threatened stocks of Columbia River chum. Between 1949 and 1988, ground-water discharge to these springs along the Columbia River, between Vancouver and Camas, decreased on average by approximately 5.22 cfs, or 27 % (McFarland and Morgan 1996). Wildrick et al (1998) attributes this decline to withdrawal of ground water and urban construction that increased impervious surfaces. The extent and conditions of these chum spawning areas and the source of these springs should be identified and then protected from future nearshore development and additional groundwater withdrawals.

While only 26 percent of the spawning substrate in the Salmon Creek basin is located above 182nd Avenue in upper Salmon, Morgan, and Rock Creeks, stream surveys (Wille 1989) found that nearly one-half of all steelhead and coho spawning occurred in these reaches. These upper reaches also generally have the best riparian areas, substrates, and water quality within Salmon Creek, and these areas are the least affected by the cumulative impacts to stream channels that result from loss of forest cover and high levels of impervious surfaces. Protection of these headwater reaches is the highest priority within the Salmon Creek system.

Urban and rural development within the subbasin has substantially increased impervious surfaces and reduced forest cover in many watersheds within the subbasin. Protection and enhancement of existing wetland habitat anywhere in the subbasin would help address water quality and quantity problems, reduce peak flows and enhance low flows, and contribute to channel and streambed stability. Protection and enhancement of existing wetlands would be especially critical within the Mill Creek, Curtin Creek, and Burnt Bridge Creek watersheds.

Wille (1989) estimated that salmonid populations in Salmon Creek reach only 3-5% of their potential size, assuming that habitat requirements for each species are optimized. From an analysis of stream habitat and redd surveys Wille (1989) determined that the potential spawning capacity within the Salmon Creek watershed is much larger than the actual rearing capacity. Protection and enhancement of potential rearing habitat for coho, steelhead, and/or coastal cutthroat should provide the greatest benefits for salmonid production within this stream system.

<u>Washougal River Subbasin:</u>

The upper reaches of the Washougal River mainstem and its tributaries that support anadromous fish are especially critical habitat to protect for a number of reasons. These areas include some of the best, most functional habitat within WRIA 28. Cool, clear water from these reaches helps buffer downstream impacts to water quality, and somewhat healthy riparian areas provide LWD recruitment to downstream reaches. These streams provide some of the best remaining habitat for summer steelhead stocks in the lower Columbia River, which is already limited to just four major stream systems.

Most of the functional habitat within the Little Washougal River, and the North Fork Washougal also occurs within the headwater areas. Protection and enhancement of these headwater areas will benefit multiple stocks of salmon, steelhead, and coastal cutthroat trout, as well as help contribute cool, clear water and LWD to downstream habitats.

A substantial amount of the floodplain and side-channel habitat within the Washougal Subbasin has been lost or disconnected from the streams. Protection and enhancement of these habitats is critical for salmonids that use these areas for freshwater rearing and spawning.

Urban and rural development within the Washougal Subbasin has also substantially increased impervious surfaces and reduced forest cover. Protection and enhancement of existing wetland habitat anywhere in the subbasin would help address water quality and quantity problems, reduce peak flows and enhance low flows, and contribute to channel and streambed stability. Protection and enhancement of existing wetlands would be especially critical within the Little Washougal and Lacamas Creek watersheds.

Historical accounts noted that numerous chum salmon once returned to the lower reaches of Lacamas Creek to spawn. Riparian conditions along portions of the lower reaches are some of the best in the Washougal subbasin, and the potential still exists for this area to support chum spawning. This is an important area to protect and restore. However, intensive development along upstream reaches and water withdrawals continue to threaten water quality and water quantity. Protection and restoration of this habitat will require more than just addressing localized problems; it will require major changes in the operation of the dams and reservoirs, and major improvements in water quality.

Bonneville Tributaries Subbasin:

Protection of chum spawning areas in Hamilton and Hardy Creeks is one of the highest priorities within the subbasin, as well as in WRIA 28 and the entire lower Columbia River basin. Protection of these spawning sites requires protection of the headwaters of these streams to maintain good water quality and the natural hydrologic regime, and to minimize fine sediment inputs.

Chum and fall chinook spawn in the mainstem of the Columbia River just downstream of Bonneville Dam near Ives and Pierce Islands. These spawning sites provide critical habitat for listed chum species in the lower Columbia, especially during dry years when low flows limit the availability of tributary spawning habitat.

Hundreds of chum salmon once returned to spawn within the spring-fed areas along Duncan Creek. With the construction of a new passage facility, chum salmon again have access to this productive tributary. Considering the limited availability of quality spawning habitat for chum in the lower Columbia, protection and enhancement of these springs is also a high priority within the Bonneville Tributaries Subbasin.

According to Barndt et al. (2000: unpublished) the habitat in Gibbons Creek above Hans Nagel Road is the best in the watershed. This stream reach has the potential to support a healthy population of coho and steelhead, but it vulnerable to the same problems that occur in the rest of the drainage. A long-term plan to protect this reach is needed, since the adjoining properties are entirely privately owned and the removal of riparian vegetation, the addition of runoff from development, and/or removal of instream large woody debris would decrease its value as fish habitat. Also, any degradation that occurs in the uppermost reaches of the mainstem would adversely affect downstream habitat.

In the future, as more information and analyses of habitat-limiting factors become available, it would be desirable to explore the concept of protecting or restoring habitat-forming processes. This concept addresses in detail the dependence of habitat on what is happening upstream. If the habitat-forming factors have been altered by land-use activities, there may great risk in attempting to improve the downstream habitat without first correcting the upstream disturbances. This approach has been recommended in the draft "Statewide Watershed Assessment Guidance for Salmon," February 2000, by the Governor's Salmon Recovery Office.

DATA GAPS

The ability to determine what factors are limiting salmonid production, and to prioritize those factors within and between drainages, is limited by the current lack of specific habitat assessment data. Some stream surveys have been conducted along Salmon Creek, Burnt Bridge Creek, Gibbons Creek, and most of the anadromous streams within the Columbia River Gorge to help quantify habitat condition and fish usage. However, some of these surveys are over 12 years old and conditions have habitat conditions have changed appreciably since then. Stream survey methodologies also varied considerably for some of these stream systems. Collecting additional this baseline data and updating older data will be critical for developing effective recovery and restoration plans, for prioritizing future recovery efforts, and for monitoring the success of those efforts. The following list identifies specific areas where the collection of additional data could improve understanding of WRIA 28 habitat limiting factors.

Watershed Condition

Understanding how various processes are operating at the basin level would substantially benefit the analysis of habitat limiting factors. With an understanding and quantification of the hydrology, sediment input and transport, nutrient cycling, and the vegetation structure of the basin, it becomes possible to better understand the relationships and develop connections between specific land uses and subsequent changes in aquatic ecosystems. For example, at what level of impervious surfaces, road density and/or forest cover within a basin do peak flows increase to levels that significantly alter stream channel morphology and sediment transport? Without this watershed-scale picture, we often attempt to treat the symptoms without understanding the disease, and our restoration efforts fail. Studies that would benefit the understanding of conditions within every major basin within WRIA 28 include:

- GIS analysis, with groundtruthing, of the vegetation structure and composition of each watershed and its riparian zones using recent satellite and aerial photos;
- A thorough peak flow analysis examining the hydrologic maturity of forested watersheds, road networks, and the percent of impervious surfaces within the urban areas of the subbasins of WRIA 28;
- A sediment budget that describes major input and transport within each subbasin;
- Stream surveys that provide data on stream channel types and conditions and streambed substrates.

Also, an important data gap within most subbasins is the historical condition of salmonid habitat. Some information on historical floodplain conditions, plant communities, and hydrology can be gleaned from historical land-use documents. This historical background data can add significantly to our understanding of limiting factors within the basin.

Distribution and Condition of Stocks

Information was generally lacking on the distribution and recent condition of most stocks within WRIA 28. Data on the condition of salmon stocks in the lower Columbia River was last compiled and analyzed as part of the SASSI report in 1992, and steelhead stock condition was last published as part of the Lower Columbia Steelhead Conservation Initiative (LCSCI) in 1997. Updated information on the status of wild stocks will be critical for both focusing restoration efforts and monitoring the success of the restoration efforts. It will be important to monitor stock status by maintaining, or if possible, expanding ongoing trapping efforts and carcass and redd surveys.

It will also be important to increase the scope of existing spawning ground and stream surveys within WRIA 28. These surveys only cover a limited amount of habitat within each basin. There is minimal data on fish distribution available for areas like the smaller tributaries and floodplain habitats. Conducting additional fish surveys on smaller tributaries and in areas outside of standard index reaches would provide a much better picture of how various life-history stages for each species utilize habitat within the WRIA and will help identify where habitat may be limited.

TAG members were concerned about the impact of hatchery fish interacting with wild populations of steelhead on the spawning grounds above the Skamania Hatchery on the North Fork Washougal. It will be important to assess the extent of hatchery influence on wild fish in the Washougal Subbasin, especially in the North Fork.

Access

Various culvert inventories have been completed within portions of WRIA 28 that provide some guidance as to the severity of the barrier for both juvenile and adult passage, as well as the quality of the habitat both upstream and downstream of any blockages. Without this data it is difficult if not impossible to prioritize culvert removal and/or repair. Developing a complete inventory of passage barriers, using a consistent methodology and that includes habitat surveys above and below the blockage would be especially important within the Little Washougal River system, Gibbons Creek, Burnt Bridge Creek, and along many of the tributaries within the Bonneville Tributaries Subbasin.

The flushing channel into Vancouver Lake is another area where data is lacking on fish passage. Areas like Vancouver Lake and its associated sloughs and wetlands can potentially provide important rearing areas for both local stocks and downstream migrants from the upper Columbia (Knutzen and Cardwell 1984). Under certain conditions the flushing channel may attract downstream migrants into Vancouver Lake, and at times locally produced smolts may use the flushing channel instead of Lake River to move into the Columbia (Knutzen and Cardwell 1984). An assessment is needed to determine potential passage issues within the flushing channel and its structures.

Low flow also potentially limits access and movement within various drainages throughout WRIA 28. In many areas this a natural condition; however, water withdrawals and various land uses have contributed appreciably to this problem in some streams within WRIA 28. Additional assessment is needed to determine the extent and potential cause of low flow problems, especially within, the Little Washougal and its tributaries, Boulder and Jones Creeks, Salmon Creek, and various streams within the Bonneville Tributaries where flow is intermittent.

An ongoing effort by Clark Public Utilities and the US army Corps of Engineers proposes to collect passage barrier data for the Salmon Creek basin. The Draft LFA for Salmon Creek (HDR 2000) identified access data gaps for Salmon Creek and its tributaries including:

- No data were found linking flow regimes with limitations on salmonid migrations, movement and rearing behavior.
- There are only limited data available on culverts or other barriers, which impede fish passage on private lands in the Salmon Creek Basin. The existing culvert passage information does not include considerations of juvenile salmonid movement, migration or passage.
- No data were found on access to spawning and rearing habitat, which has been restricted by dikes, levees, roads, and other developments on Lake River or on Salmon Creek and its tributaries.

Floodplain Connectivity

Floodplain habitat and functions have been lost or altered in most major steams within the subbasin. Development continues within the areas floodplains even today. We are gaining a better understanding of the importance of floodplain habitats, such as off-channel ponds, beaver ponds, and protected side channel sloughs, for coho and other salmonids that rely on these low-gradient areas for winter rearing habitat (Scarlett and Cedarholm 1984; Peterson and Reid 1984). Various studies (Pess et al. 1999; Beechie et al. 1994) illustrate the potential loss of productivity that occurs when floodplain habitat is lost and disconnected from river systems. Alterations of floodplain habitat in WRIA 28 often occurred early in the last century and the extent of these changes is now difficult to calculate. It will be important to identify the extent of historical floodplain habitat and then to identify areas where floodplain and off channel habitat could be enhanced or restored.

Some of the most important areas to focus initial floodplain surveys would include the lower reaches of the Camas Slough, Washougal River, and Little Washougal River. State Route 14, the railroad, and other development along the Columbia have reduced or eliminated already limited low gradient/floodplain habitat in many of the Columbia Gorge area streams. The lower reaches of these streams also need assessment to identify areas where floodplain and off-channel habitat can be enhanced or restored.

Most of the historic floodplain habitat surrounding Vancouver Lake and Lake River has been disconnected from the Columbia except at the highest flows. Habitat alterations have also reduced the quality of the remaining habitat. Fish surveys in the early 1980's suggested that chinook juveniles that entered Vancouver Lake had excellent growth; considerably better than juveniles that were captured in the Columbia River (Knutzen and Cardwell 1984). There are likely areas within Vancouver Lake and Lake River that still provide important rearing habitat for juvenile salmonids; yet, there is very limited data on fish use and habitat conditions within these areas.

Floodplain surveys are already proposed for Salmon Creek as part of the LFA that Clark Public Utilities and the US Army Corp of Engineers are conducting (HDR 2000). Data gaps for Salmon Creek floodplain connectivity identified in the Draft LFA (HDR 2000) included:

- No historical floodplain area data were found.
- No information on levees, dikes, roads or other development that restrict floodplain connectivity was found.
- No data have been provided for flood protection work, which has resulted in the loss of floodplain connectivity.
- No historical information on loss of floodplain wetlands due to diking or levee-building was found.

Low gradient habitat in Greenia Creek could increase potential rearing habitat within Hardy Creek; however, the potential impacts to western pond turtles needs assessment before the area can be reopened.

Streambed Sediment Conditions

Data on streambed sediment conditions is generally lacking for portions of WRIA 28. Exceptions include portions of Salmon Creek and its tributaries, and some stream surveys in the Bonneville Tributaries Subbasin. However, stream surveys conducted for many of the Bonneville Tributaries did not include data on substrate conditions, and the data for Salmon Creek is over 12 years old and conditions may have changed appreciably in that period of time. The flood events of 1996 and additional development within the Salmon Creek may have significantly altered the instream habitat, substrates, and sedimentation since the 1988 surveys.

According to the Draft Salmon Creek LFA (HDR 2000), "although many locations were identified where sediment input is a concern, there is little specific information. There has not been a consistent methodology to document excessive sediment sources or estimate the amount of mass wasting. … Thus, repeating a sample of the Harvester (1989) study on habitat to determine if conditions from 1987 and 1988 are representative of current conditions is encouraged. In conjunction with this study of channel conditions, data should be collected to quantify, identify, and map spawning substrate areas and the amount of sedimentation in spawning substrates. Future periodic monitoring as above could provide an indicator of change in conditions.

Clark County does have an erosion control inspection and enforcement division. To date, however, there does not seem to be a database, or reporting system that estimates sediment supply to the stormwater conveyance system in areas where the control methods may not have been effective.

Other data gaps include:

- No printed data on mass wasting and road density.
- No baseline, historical, and pre-settlement sediment supply or substrate condition data.
- No analysis of effects of human activities on sediment processes.
- No data on recent riparian and instream enhancement projects in the basin exemplifying effects on sedimentation processes."

Specific data on sediment conditions is lacking for the entire Washougal River Subbasin. Streambed sediment surveys are needed throughout the basin. Priority areas to conduct these surveys would include the Little Washougal system and Winkler Creek where ATV use, development activities, and cattle are all likely contributing to excess fine sediment inputs.

The lower reaches of Burnt Bridge Creek and the Columbia Slope Tributaries (tributaries draining directly into the Columbia between Lake river and the Washougal River) have areas where springs historically and presently support chum salmon spawning. Surveys are needed to determine the condition of these habitats and their potential value as to chum stocks.

Channel Conditions

Data on channel conditions within many of the streams within WRIA 28 was also generally lacking, especially for the Washougal River Subbasin. Stream surveys from the Forest Service (Larson 2001) on many of the Bonneville Tributaries, USFWS on Gibbons and Hardy Creeks (Barndt et al. 2000), and Clark Conservation District on Salmon Creek (Wille 1989) provided the most comprehensive data for channel conditions within WRIA 28. However, in most areas data collection occurred before the 1996 floods and increasingly rapid urban and rural development, and the survey methodologies used by the federal agencies were not consistent with the surveys conducted by Clark Conservation District.

As part of the ongoing LFA work in the Salmon Creek watershed, HDR (2000) suggested, "channel conditions data collected prior to flood events of 1996 may not reflect current conditions. Therefore, a sub-sample of reaches from the Harvester (1989) study should be re-surveyed to determine the applicability of these data to existing conditions. Concurrently, collecting pool depth data would be useful for the pool quality parameter of an LFA." If additional stream survey data is collected on channel conditions within Salmon Creek or any stream system within the subbasin, methodologies should be consistent with updated USFS Level II stream inventories.

Stream surveys are also needed to establish baseline channel conditions within the Washougal River Subbasin. TAG members noted that the lack of quality pool habitat and instream LWD is major limiting factor in many of the stream systems within the Washougal. Collecting baseline data on channel conditions would provide a better idea to what extent these problems occur within the subbasin, and help identify critical areas and specific actions that are needed to benefit salmon and steelhead habitat.

Stream surveys in the Little Washougal and Winkler Creek could also identify areas where ATV use and cattle have reduced bank stability and altered stream channels.

Riparian Conditions

Riparian conditions are generally considered poor throughout WRIA 28; however, that assessment used very coarse-scale land cover data dating back to 1993. This data needs to be updated using more recent satellite and aerial photos for vegetation cover, and additional groundtruthing should be incorporated. Where possible, formal riparian inventories should be conducted that include data on growth, age, species, and disturbance mechanisms for riparian vegetation.

Water Quality

Water quality data is generally limited within WRIA 28 to areas within Salmon Creek, Burnt Bridge Creek, Gibbons Creek, and some on the mainstem Washougal. Clark Public Utilities has a fairly comprehensive water quality monitoring program in place for the Salmon Creek watershed. The City of Vancouver also had a comprehensive water quality program in place for Burnt Bridge Creek until they suddenly stopped collecting data about two years ago. Water quality monitoring on Burnt Bridge Creek should resume as soon as possible. Ecology's TMDL process on Gibbons Creek and Salmon Creek will hopefully provide sufficient data to identify major non-point water pollution sources and develop plans to address these problems. Similar processes are ongoing in the Lacamas Creek watershed through Clark County to identify water quality problems and work toward potential solutions.

Most of the water quality (mainly temperature) data available for the Washougal River watershed comes from the efforts of volunteer groups and from the hatcheries. These data collection efforts need to be supported and expanded where possible to provide a better idea of where water quality problems occur and to find potential solutions for these problems. Minimal amounts of water quality monitoring has occurred for the streams within the Bonneville Tributaries Subbasin, and the only ongoing monitoring efforts occur on USFWS lands on Hardy and Gibbons Creeks.

Elevated stream temperatures are consistent problems on many systems within WRIA 28, especially within many of the lower elevation watersheds where land-use impacts and hydrologic modifications have been extensive. While this report identifies a number of areas where water temperatures may be limiting salmonid production, there may also be other areas within WRIA 28 with significant problems that haven't as yet been identified because of insufficient water quality monitoring. Without comprehensive coverage of all systems within the WRIA, it is difficult to pull together a picture of what types of problems are occurring and where. Water quality problems are generally no longer associated with point sources of pollution, but are now more a matter of cumulative impacts from a number of land uses across the landscape. Identifying the relationships between specific land-uses and associated water quality problems and then finding solutions to these problems, requires an extensive and ongoing monitoring program that extends into the smaller tributaries, as well as the mainstem rivers. This information can then be used to develop priorities at both the site specific and watershed scale.

One major problem with existing water quality monitoring programs is that water quality standards are not necessarily based on the needs of fish, and restoration strategies based on these standards may not adequately protect fish. It will be important to update water quality standards to assure protection of threatened and endangered fish species.

Some specific areas that need additional study include:

- Lake River provides the major migration corridor for salmonids within the Lake River Subbasin, and only minimal amounts of water quality data are available. What data exists points to potentially significant water temperature problems that could limit rearing success and potentially affect migration. Water quality monitoring in Lake River would benefit the analysis proposed for Salmon Creek by CPU and the Army Corp.
- TAG members were concerned about the potential stormwater impacts from existing and additional development at North Bonneville. Hamilton Creek provides one of the few remaining chum spawning streams within the lower Columbia, and the spawning sites are just downstream from this growing community. It will be important to determine impacts to water quality from stormwater inputs into Hamilton Creek.
- Low flows likely contribute to elevated water temperatures in many stream systems within WRIA 28. While summer flows are naturally low in most streams within the Subbasin, land uses and water withdrawals in some streams further reduce flow. Collection and analysis of additional data on streamflow and water temperatures is needed on streams such as Boulder and Jones Creeks on the Little Washougal, Lacamas Creek, Burnt Bridge Creek, and Salmon Creek where various land uses and water withdrawals affect streamflow and therefore water quality.

Water Quantity

The Department of Ecology, in cooperation with the Department of Fish and Wildlife, conducted an instream flow study at various isolated sites on many of the stream systems within WRIA 28. While the study identified the optimum flow for both spawning and rearing for various species, it did not identify flows necessary for incubation of fish eggs, smolt out-migration, fish passage to spawning grounds, and prevention of stranding fry and juveniles. Meeting these needs is required when setting minimum instream flows. Nor did the study consider other variables that might also be impacted by low flows such as water temperature, water quality, and sediment load (Caldwell et al. 1999). The IFIM studies collected only a limited amount of flow data for smaller tributaries in WRIA 28 during the summer months of 1998, and only for a limited number of sites. This data collection process could be expanded, and include a process for identifying necessary flows for other life-history stages.

The data from Ecology's IFIM study shows that low-flow may be limiting rearing habitat for salmonid juveniles in most measured streams during the summer and fall months. These are also the times when elevated water temperatures stress juveniles rearing in already limited habitat. The combination of these factors needs additional research to determine the impacts to fish that must find suitable rearing habitat within fresh water year-round. It will be important to incorporate this additional information into the models before determining appropriate minimum instream flows.

Private and public water diversions also likely further reduce low summer flows. A comprehensive assessment of all water withdrawals and groundwater connections to streamflow is needed to help determine what proportion of any reduction in seasonal flows in the various basins is due to capture by wells or surface withdrawals.

Many of the stream gauges that could provide critical information on stream flows within WRIA 28 are no longer in use. The TAG suggested restoring and monitoring as many of these gages as possible. Only with long-term flow data can many of the associations between alterations in land use, streamflow, and habitat conditions be made.

The Columbia Slope tributaries (between Vancouver Lake and the Washougal River) are small systems that are fed mainly by springs. Between 1949 and 1988, ground-water discharge to these springs along the Columbia River decreased by approximately 10 cfs, or 42 %. Wildrick et al (1998) attributes this decline to the pumping of wells in the uplands to the north, because the loss of spring flow corresponds closely in timing with the decline of heads in the aquifers that feed the springs. Chum were recently found spawning in spring fed areas along the north Columbia River shoreline near the I-205 Bridge, and it will be important to asses the connection between recently discovered spawning sites and groundwater influences. It will also be important to identify potential impacts to water volume and quality within these springs.

Forest cover data and road densities were used in this study to identify areas with peak flow concerns within WRIA 28. However, in more urbanized areas an impervious surface analysis would better identify areas where increased peak flows are likely impacting stream channels and salmonid habitat. In some urban areas this analysis is underway, while in other areas the GIS data for this type of analysis is lacking. A consistent methodology for collecting data on existing and proposed land use and assessing the amount of impervious surfaces created needs to be developed and utilized by all jurisdictions within WRIA 28.

Biological Processes

Escapement for most anadromous salmonids is well below historic levels, and aquatic ecosystems are likely negatively affected by the loss of nutrients. Assessment of nutrient levels within the various subbasins is needed to quantify the extent of the impacts to aquatic communities as well as the potential to enhance salmonid habitat with carcass planting.

Surveys of the aquatic macroinvertebrate community have been conducted in reaches of Burnt Bridge Creek (Gaddis 1994), Salmon Creek (Pratt 1998), and Gibbons Creek (Barndt et al. 2000). These types of studies can provide an excellent baseline indicator of habitat quality and aquatic conditions, and they can be easily duplicated at a later date to monitor changes within stream systems. This type of baseline data is needed for all major streams within WRIA 28.

There are a number of areas where hydrological modifications, introduced species, and hatchery operations may be favoring salmonid predators, and increasing disease and competition for resources. The extent of these impacts is generally unknown, and assessment of the potential impacts to salmonids from these activities will be especially important within Lake River, Vancouver Lake flushing channel, Camas Slough and the Washougal River, and Greenleaf Slough.

Non-native plant species, such as reed canary grass and Himalayan blackberries inhibit the reestablishment of native riparian vegetation. Numerous riparian restoration projects are underway within WRIA 28, and there have been a variety of methods used to remove invasive species and reestablish native plants. It will be important to monitor the success of these projects and the various methods used to help guide future riparian restoration projects.

Impounding water behind the Duncan Creek Dam to create a recreational lake during the summer months alters the natural hydrology and sediment movement within the watershed. What affects this practice has upon the aquatic ecosystem, and subsequently, critical listed stocks of lower Columbia River chum salmon, is generally unknown. It will be important to monitor habitat conditions, aquatic health, and salmonid use within Duncan Creek and then practice adaptive management for the timing and operation of the dam to assure that this restoration project benefits aquatic health and listed species.

Habitats in Need of Protection

Identification of important habitats that need protection within WRIA 28 was based on the collective knowledge of the TAG members. While the fisheries and habitat experts on a stream system are likely to identify the most critical habitats, it would be important to develop a standardized methodology for identifying these areas that could then be applied consistently within stream systems, as well as across the region. This standardized methodology would also help identify specific data needs and data gaps.

Additional data on the distribution and abundance of the various species during all life-history stages would also benefit the analysis of which habitats are truly the most critical to protect within each watershed. This baseline information is necessary to both identify critical areas for each life-history phase and to monitor recovery success over time.

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APPENDICES

Appendix A Maps

Several maps have been included with this report for your reference. The maps are appended to the report as a separate electronic file. The maps are included as a separate electronic file to enable the reader to utilize computer multi-tasking capabilities to simultaneously bring up the map and associated text. For printed hard copies of the report add the 11 by 17 inch maps to this appendix. Below is a list of maps that are included in the WRIA 28 map appendix/file:

Appendix B Salmonid Habitat Condition Rating Standards for Identifying Limiting Factors

Under the Salmon Recovery Act (passed by the legislature as House Bill 2496, and later revised by Senate Bill 5595), the Washington Conservation Commission (WCC) is charged with identifying the habitat factors limiting the production of salmonids throughout most of the state. This information should guide lead entity groups and the Salmon Recovery Funding Board in prioritizing salmonid habitat restoration and protection projects seeking state and federal funds. Identifying habitat limiting factors requires a set of standards that can be used to compare the significance of different factors and consistently evaluate habitat conditions in each WRIA throughout the state.

In order to develop a set of standards to rate salmonid habitat conditions, several tribal, state, and federal documents that use some type of habitat rating system were reviewed (see Table 58). The goal was to identify appropriate rating standards for as many types of habitat limiting factors as possible, with an emphasis on those that could be applied to readily available data. Based on the review, it was decided to rate habitat conditions into three categories: Good, Fair, and Poor. For habitat factors that had wide agreement on how to rate habitat condition, the accepted standard was adopted by the WCC. For factors that had a range of standards, one or more of them were adopted. Where no standard could be found, a default rating standard was developed, with the expectation that it will be modified or replaced as better data become available.

The ratings adopted by the WCC are presented in Table 59. These ratings are not intended to be used as thresholds for regulatory purposes, but as a coarse screen to identify the most significant habitat limiting factors in a WRIA. They also will hopefully provide a level a consistency between WRIAs that allows habitat conditions to be compared across the state. However, for many habitat factors, there may not be sufficient data available to use a rating standard or there may be data on habitat parameters where no rating standard is provided. For these factors, the professional judgment of the TAG should be used to assign the appropriate ratings. A set of narrative standards will be developed in the near future to provide guidance in this situation.

In some cases there may be local conditions that warrant deviation from the rating standards presented here. This is acceptable as long as the justification and a description of the procedures that were followed are clearly documented in the limiting factors report. Habitat condition ratings specific to streams draining east of the Cascade crest were included where they could be found, but for many parameters they were not. Additional rating standards will be included as they become available. In the meantime, TAGs in these areas will need to work with the standards presented here or develop alternatives based on local conditions. Again, if deviating from these standards, the procedures followed should be clearly documented in the limiting factors report.

Table 58. Source documents

Code	Document	Organization
Hood Canal	Hood Canal/Eastern Strait of Juan de Fuca Summer Chum Habitat Recovery Plan, Final Draft (1999)	Point No Point Treaty Council, Skokomish Tribe, Port Gamble S'Klallam Tribe, Jamestown S'Klallam Tribe, and Washington Department of Fish and Wildlife
ManTech	An Ecosystem Approach to Salmonid Conservation, vol. 1 (1995)	ManTech Environmental Research Services for the National Marine Fisheries Service, the US Environmental Protection Agency, and the US Fish and Wildlife Service
NMFS	Coastal Salmon Conservation: Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast (1996)	National Marine Fisheries Service
PHS	Priority Habitat Management Recommendations: Riparian (1995)	Washington Department of Fish and Wildlife
Skagit	Skagit Watershed Council Habitat Protection and Restoration Strategy (1998)	Skagit Watershed Council
WSA	Watershed Analysis Manual, v4.0 (1997)	Washington Forest Practices Board
WSP	Wild Salmonid Policy (1997)	Washington Department of Fish and Wildlife

Table 59. WCC salmonid habitat condition ratings

Habitat Factor	**Parameter/Unit**	**Channel Type**	**Poor**	**Fair**	**Good**	**Source**
Access and Passage						
Artificial Barriers	% known/potential habitat blocked by artificial barriers	All	>20%	10-20%	<10%	WCC
Floodplains						
Floodplain Connectivity	Stream and off-channel habitat length with lost floodplain connectivity due to incision, roads, dikes, flood protection, or other	<1% gradient	>50%	10-50%	<10%	WCC
Loss of Floodplain Habitat	Lost wetted area	<1% gradient	>66%	33-66%	<33%	WCC
Channel Conditions						
Fine Sediment	Fines < 0.85 mm in spawning gravel	All – Westside	>17%	11-17%	≤11%	WSP/WSA / NMFS/Hood Canal

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
	Fines < 0.85 mm in spawning gravel	All – Eastside	>20%	11-20%	≤11%	NMFS
Large Woody Debris	pieces/m channel length	≤4% gradient, <15 m wide (Westside only)	<0.2	0.2-0.4	>0.4	Hood Canal/Skagit
	or use Watershed Analysis piece and key piece standards listed below when data are available					
	pieces/channel width	<20 m wide	<1	1-2	2-4	WSP/WSA
	key pieces/channel width*	<10 m wide (Westside only)	<0.15	0.15-0.30	>0.30	WSP/WSA
	key pieces/channel width*	10-20 m wide (Westside only)	<0.20	0.20-0.50	>0.50	WSP/WSA

* Minumim size to qualify as a key piece:

BFW (m)	Diameter (m)	Length (m)
0-5	0.4	8
6-10	0.55	10
11-15	0.65	18
16-20	0.7	24

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Percent Pool	% pool, by surface area	<2% gradient, <15 m wide	<40%	40-55%	>55%	WSP/WSA
	% pool, by surface area	2-5% gradient, <15 m wide	<30%	30-40%	>40%	WSP/WSA

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
	% pool, by surface area	>5% gradient, <15 m wide	<20%	20-30%	>30%	WSP/WSA
	% pool, by surface area	>15 m	<35%	35-50%	>50%	Hood Canal
Pool Frequency	channel widths per pool	<15 m	>4	2-4	<2	WSP/WSA
	channel widths per pool	>15 m	-	-	chann width / pools/ mile / cw/ pool 50’ 26 4.1 75’ 23 3.1 100’ 18 2.9	NMFS
Pool Quality	pools >1 m deep with good cover and cool water	All	No deep pools and inadequate cover or temperature, major reduction of pool volume by sediment	Few deep pools or inadequate cover or temperature, moderate reduction of pool volume by sediment	Sufficient deep pools	NMFS/WSP/WSA
Streambank Stability	% of banks not actively eroding	All	<80% stable	80-90% stable	>90% stable	NMFS/WSP
Sediment Input						
Sediment Supply	$m^3/km^2/yr$	All	> 100 or exceeds natural rate*	-	< 100 or does not exceed natural rate*	Skagit
	* Note: this rate is highly variable in natural conditions					

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Mass Wasting		All	Significant increase over natural levels for mass wasting events that deliver to stream	-	No increase over natural levels for mass wasting events that deliver to stream	WSA
Road Density	mi/mi^2	All	>3 with many valley bottom roads	2-3 with some valley bottom roads	<2 with no valley bottom roads	NMFS
	Or use results from Watershed Analysis where available					
Riparian Zones						
Riparian Condition	• riparian buffer width (measured out horizontally from the channel migration zone on each side of the stream) • riparian composition	Type 1-3 and untyped salmonid streams >5' wide	<75' or <50% of site potential tree height (whichever is greater) OR Dominated by hardwoods, shrubs, or non-native species (<30% conifer) unless these species were dominant historically.	75'-150' or 50-100% of site potential tree height (whichever is greater) AND Dominated by conifers or a mix of conifers and hardwoods (≥30% conifer) of any age unless hardwoods were dominant historically.	• >150' or site potential tree height (whichever is greater) AND • Dominated by mature conifers (≥70% conifer) unless hardwoods were dominant historically	WCC/WSP
	• buffer width • riparian composition	Type 4 and untyped perennial streams <5' wide	<50' with same composition as above	50'-100' with same composition as above	>100' with same composition as above	WCC/WSP

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
	• buffer width • riparian composition	Type 5 and all other untyped streams	<25' with same composition as above	25'-50' with same composition as above	>50' with same composition as above	WCC/WSP
Water Quality						
Temperature	degrees Celsius	All	>15.6° C (spawning) >17.8° C (migration and rearing)	14-15.6° C (spawning) 14-17.8° C (migration and rearing)	10-14° C	NMFS
Dissolved Oxygen	mg/L	All	<6	6-8	>8	ManTech
Hydrology						
Flow	hydrologic maturity	All	<60% of watershed with forest stands aged 25 years or more	-	>60% of watershed with forest stands aged 25 years or more	WSP/Hood Canal
		or use results from Watershed Analysis where available				
	% impervious surface	Lowland basins	>10%	3-10%	≤3%	Skagit
Biological Processes						
Nutrients (Carcasses)	Number of stocks meeting escapement goals	All Anadromous	Most stocks do not reach escapement goals each year	Approximately half the stocks reach escapement goals each year	Most stocks reach escapement goals each year	***WCC***
Lakes (further work needed)						

Habitat Factor	**Parameter/Unit**	**Channel Type**	**Poor**	**Fair**	**Good**	**Source**
Estuaries (further work needed)						

Appendix C Fish Distribution Definitions

The following definitions were used to develop fish distribution maps for WRIA 28:

Known:

Habitat that is documented to presently sustain fish populations (published sources, survey notes, first-hand sightings, etc.): or, habitat with records of fish use (which may or may not be known to have been extirpated for some reason). This includes habitat used by all life history stages for any length of time (i.e. intermittent streams which contain water during flood flows that provides refuge habitat for a period of hours or days).

Presumed:

Habitat with no records of known fish use, but that is below any known natural barrier (including sustained 12% gradient) and otherwise conforms to species-specific habitat criteria.

Potential:

Habitat above human-caused blockages or obstructions that could be opened to fish use and that is below any known natural barrier (including sustained 12% gradient) and otherwise conforms to species-specific habitat criteria.

Artificial:

Includes habitat with Known presence of salmonids that are supported by an active fish passage operation (such as a trap and haul facility) or a structure providing passage around a dam or natural passage barrier. Known habitat occupied exclusively by hatchery outplants or strays may also be included.

Appendix D: Glossary

303 (d) List: The federal Clean Water Act requires states to maintain a list of stream segments that do not meet water quality standards. The list is called the 303(d) list because of the section of the Clean Water Act that makes the requirement.

Adaptive management: Monitoring or assessing the progress toward meeting objectives and incorporating what is learned into future management plans.

Adfluvial: Migratory between lakes and rivers or streams or, life history strategy in which adult fish spawn and juveniles subsequently rear in streams but migrate to lakes for feeding as subadults and adults. Compare fluvial.

Administratively Withdrawn Areas: A land management designation for federally-administered lands within the range of the northern spotted owl (USFS and BLM 1994). Administratively Withdrawn Areas are identified in current Forest and District Plans or draft plan preferred alternatives and include recreation and visual areas, back county, and other areas where management emphasis precludes scheduled timber harvest.

Aggradation: The geologic process of filling and raising the level of the streambed or floodplain by deposition of material eroded and transported from other areas.

Alluvial: Deposited by running water.

Alluvial fan: A relatively flat to gently sloping landform composed of predominantly coarse grained soils, shaped like an open fan or a segment of a cone, deposited by a stream where it flows from a mountain valley onto a plain or broader valley, or wherever the stream gradient suddenly decreases. Alluvial fans typically contain several to many distributary channels that migrate back and forth across the fan over time. This distribution of flow across several stream channels provide for less erosive water velocities, maintaining and creating suitable rearing salmonid habitat over a wide range in flows.

Anadromous fish: Species that are hatched in freshwater mature in saltwater, and return to freshwater to spawn.

Anchor ice: Forms along the channel bottom form the accumulation of frazil ice particles on the rough surfaces of coarse bottom sediments and on the lee sides of pebble, cobbles, and boulders.

Aquifer:

1. A subsurface layer of rock permeable by water. Although gravel, sand sandstone and limestone are the best conveyors of water, the bulk of the earth’s rock is composed of clay, shale and crystalline.

2. A saturated permeable material (often sand, gravel, sandstone or limestone) that contains or carries groundwater.

3. An underground, water-bearing layer of earth, porous rock, sand, or gravel, through which water can seep or be held in natural storage. Aquifers generally hold sufficient water to be used as a water supply.

Basin: The area of land that drains water, sediment and dissolved materials to a common point along a stream channel.

Basin flow: Portion of stream discharge derived from such natural storage sources as groundwater, large lakes, and swamps but does not include direct runoff or flow from stream regulation, water diversion, or other human activities.

Bioengineering: Combining structural, biological, and ecological concepts to construct living structures for erosion, sediment, or flood control.

Biological Diversity (biodiversity): Variety and variability among living organisms and the ecological complexes in which they occur; encompasses different ecosystems, species, and genes.

Biotic Integrity: Capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region; a system's ability to generate and maintain adaptive biotic elements through natural evolutionary processes.

Biological oxygen demand: An indirect measure of the concentration of biologically degradable material present in organic wastes. It usually reflects the amount of oxygen consumed in five days by biological processes breaking down organic waste.

Braided stream: Stream that forms an interlacing network of branching and recombining channels separated by branch islands or channel bars.

Buffer: An area of intact vegetation maintained between human activities and a particular natural feature, such as a stream. The buffer reduces potential negative impacts by providing an area around the feature that is unaffected by this activity.

Capacity: the amount of available habitat for a specific species or lifestage within a given area. Capacity is a density-dependent measure of habitat quantity.

Carrying capacity: Maximum average number or biomass of organisms that can be sustained in a habitat over the long term. Usually refers to a particular species, but can be applied to more than one.

Channelization: Straightening the meanders of a river; often accompanied by placing riprap or concrete along banks to stabilize the system.

Channelized stream: A stream that has been straightened, runs through pipes or revetments, or is otherwise artificially altered from its natural, meandering course.

Channel Migration Zone: lateral movement of channel leads to a sequence of events through time where terraces are formed and new floodplain areas are defined.

Channel Stability: Measure of the resistance of a stream to erosion that determines how well a stream will adjust and recover from changes in flow or sediment transport.

Check dams: Series of small dams placed in gullies or small streams in an effort to control erosion. Commonly built during the 1900s.

Confinement: When a channel is fixed in a specific location restricting its pattern of channel erosion and migration

Confluence: the flowing together of two or more streams, or the combined stream formed by the conjunction.

Congressionally Reserved Areas: A land management designation for federally-administered lands within the range of the northern spotted owl (USFS and BLM 1994). These areas include Wildernesses, Wild and Scenic Rivers, National Monuments, as well as other federal lands not administered by the Forest Service or BLM.

Connectivity: Unbroken linkages in a landscape, typified by streams and riparian areas.

Constriction: The narrowing of a channel that impedes the downstream movement of water or debris

Critical Stock: A stock of fish experiencing production levels that are so low that permanent damage to the stock is likely or has already occurred.

Depressed Stock: A stock of fish whose production is below expected levels based on available habitat and natural variations in survival levels, but above the level where permanent damage to the stock is likely.

Debris torrent: A type of landslide characterized by water-charged, predominantly coarse grained soil and rock fragments, and sometimes large organic material, flowing rapidly down a pre-existing channel.

Degradation: The lowering of the streambed or widening of the stream channel by erosion. The breakdown and removal of soil, rock and organic debris.

Deposition: The settlement of material out of the water column and onto the streambed.

Distributaries: A river branch flowing away from the main stream.

Diversity: Variation that occurs in plant and animal taxa (i.e., species composition), habitats, or ecosystems. See *species richness.*

Ecological restoration: Involves replacing lost or damaged biological elements (populations, species) and reestablishing ecological processes (dispersal, succession) at historical rates.

Ecosystem: Biological community together with the chemical and physical environment with which it interacts.

Ecosystem management: Management that integrates ecological relationships with sociopolitical values toward the general goal of protecting or returning ecosystem integrity over the long term.

Endangered Species Act: A 1973 Act of Congress that mandated the protection and restoration of endangered and threatened species of fish, wildlife and plants.

Endangered Species: Any species which is in danger of extinction throughout all, or a significant portion of its range, other than a species of the Class Insecta, as determined by the Secretary to constitute a pest.

Escapement: Those fish that have survived all fisheries and will make up a spawning population.

Estuarine: Of, or relating to, or formed in an estuary.

Estuary: A partly enclosed coastal body of water that has free connection to open sea, and within which seawater is measurably diluted by fresh river water.

Eutrophic: Pertaining to a lake or other body of water rich in dissolved nutrients, photosynthetically productive, and often deficient in oxygen during warm periods. Compare *oligotrophic.*

Evolutionary Significant Unit (ESU): A definition of a species used by National Marine Fisheries Service (NMFS) in administering the Endangered Species Act. An ESU is a population (or group of populations) that is reproductively isolated from other conspecific population units, and (2) represents an important component in the evolutionary legacy of the species.

Extirpation: The elimination of a species from a particular local area.

Flood: A rising and overflowing of a body of water especially onto normally dry land.

Floodplain: The low-lying, topographically flat area adjacent to a stream channel which is regularly flooded by stream water on a periodic basis and which shows evidence of the action of flowing water, such as active or inactive flood channels, recent fluvial soils, rafted debris or tree scarring. It varies in width depending on size of river, relative rates of downcutting and resistance of the bedrock in the valley walls.

Flow regime: Characteristics of stream discharge over time. Natural flow regime is the regime that occurred historically.

Fluvial: Of or pertaining to, or living in streams or rivers; also, organisms that migrate between main rivers and tributaries. Compare *adfluvial*.

Frazil ice: Thin particles of ice suspended in the water. Produced where extensive channel ice is formed and the freezing supercools the stream water producing nuclei of "frazil ice" particles.

Gabion: Wire basket filled with stones, used to stabilize streambanks, control erosion, and divert stream flow.

Genetic Diversity Unit (GDU) is defined as: A group of genetically similar stocks that is genetically distinct from other such groups. The stocks typically exhibit similar life histories and occupy ecologically, geographically and geologically similar habitats. A GDU may consist of a single stock

Geomorphology: Study of the form and origins of surface features of the Earth.

Glides: Stream habitat having a slow, relatively shallow run of water with little or no surface turbulence.

Healthy Stock: A stock of fish experiencing production levels consistent with its available habitat and within the natural variations in survival for the stock.

Hydrologic Unit Code (HUC): classification system used to describe the sub-division of hydrologic units. The codes represent the four levels of classification in the hyrdrologic unit system. The first level divides the US into 21 major geographic areas, or regions, based on surface topography, containing the drainage area of a major river or series of rivers. The second level divides the 21 regions into 222 sub-regions, which includes the area drained by a river system, a reach of a river and its tributaries in that reach, a closed basin or, a group of streams forming a coastal drainage area. The third level subdivides many of the subregions into accounting units. These 352 units nest within, or are equivalent to, the sub-regions. The fourth level is the cataloging unit, a geographic area representing part or all of a surface drainage basin, a combination of basins, or a distinct hydrologic feature. These units subdivide the sub-regions and accounting units into approximately 2150 smaller areas.

Hydrograph: A graphic representation or plot of changes in the flow of water or in the elevation of water levels plotted against time.

Hydrology: Study of the properties, distribution, and effects of water on the Earth's surface, subsurface, and atmosphere.

Interagency Aquatic Database and GIS: contains Stream Inventory information from the USFS, Oregon Department of Fish and Wildlife, and the Bureau of Land Management and can be sorted by stream width and stream gradient.

Intermittent stream: Stream that has interrupted flow or does not flow continuously. Compare *perennial stream*.

Interstitial: Between the grains (or cells or other solid objects). Having to do with the small, narrow spaces (interstices) found in between grains of sand, large cells or atoms or molecules, different tissues in the body, or within soil. The pores between minerals in a rock or the areas in a crystal which are not lattice sites.

Intraspecific interactions: Interactions within a species.

Large Woody Debris (LWD): Any large piece of relatively stable woody material having a diameter greater than 10 cm and a length greater than 3 meters. LWD is an important part of the structural diversity of streams. The nature and abundance of LWD in a stream channel reflects past and present recruitment rates. This is largely determined by the age and composition of past and present adjacent riparian stands. Synonyms include: Large Organic Debris (LOD) and Coarse Woody Debris (CWD). Specific types of large woody debris include:

Affixed logs: Singe logs or groups of logs that are firmly embedded, lodged, or rooted in a stream channel.

Deadheads: Logs that are not embedded, lodged or rooted in the stream channel but are submerged and close to the surface.

Digger log: Log anchored to the stream banks and/or channel bottom in such a way that a scour pool is formed.

Free logs: Logs or groups of logs that are not embedded, lodged or rooted in the stream channel.

Rootwad: The root mass of the tree.

Snag: A standing dead tree, or, a sometimes a submerged fallen tree in large streams. The top of the tree is exposed or only slightly submerged.

Sweeper log: Fallen tree whose bole or branches form an obstruction to floating objects.

Large Woody Debris Recruitment: The standing timber adjacent to the stream that is available to become large woody debris. Activities that disturb riparian vegetation including timber removal in riparian areas can reduce LWD recruitment. In addition, current conditions also reflect the past history of both natural and management-related channel disturbances such as flood events, debris flows, splash damming and stream cleanout.

Late-Successional Reserves (LSR’s): A land management designation for federally-administered lands within the range of the northern spotted owl (USFS and BLM 1994). Late-Successional Reserves are managed to protect and enhance conditions of late-successional and old-growth forest ecosystems, which serve as habitat for late-successional and old-growth forest related species including he northern spotted owl. Limited stand management is permitted.

Limiting Factor: Single factor that limits a system or population from reaching its highest potential.

Macroinvertebrates: Invertebrates large enough to be seen with the naked eye (e.g., most aquatic insects, snails, and amphipods).

Mass wasting: Landslide processes, including debris falls, debris slides, debris avalanches, debris flows, debris torrents, rockfalls, rockslides, slumps and earthflows, and all the small scale slumping collapse and raveling of road cuts and fills.

Matrix: A land management designation for federally-administered lands within the range of the northern spotted owl (USFS and BLM 1994).   The matrix consists of those federal lands outside of the six categories of designated areas (Congressionally Reserved Areas, Late –Successional Reserves, Adaptive Management Areas, Managed Late-Successional Area, Administratively Withdrawn Areas, and Riparian Reserves).   Most timber harvest and other silvicultural activities would be conducted in that portion of the matrix with suitable forest lands, according to standards and guidelines. Most timber harvest takes place in the matrix.

Native: Occurring naturally in a habitat or region; not introduced by humans.

Non-Point Source Pollution: Polluted runoff from sources that cannot be defined as discrete points, such as areas of timber harvesting, surface mining, agriculture, and livestock grazing.

Oligotrophic: Pertaining to a lake or other body of water characterized by extremely low nutrient concentrations such as nitrogen or phosphorous and resulting in very moderate productivity.

Parr: Young trout or salmon actively feeding in freshwater; usually refers to young anadromous salmonids before they migrate to the sea. See *smolt*.

Plunge pool: A pool created by water passing over or through a complete or nearly complete channel obstruction, and dropping vertically, scouring out a basin in which the flow radiates from the point of water entry.

Productivity: A measure of habitat quality which varies by species and lifestage. Productivity is a density-independent measure of habitat quality. Examples include, water temperature, water discharge, channel complexity, riparian condition, etc.

Rain-on-snow events: The rapid melting of snow as a result of rainfall and warming ambient air temperatures. The combined effect of rainfall and snow melt can cause high overland stream flows resulting in severe hillslope and channel erosion.

Rearing habitat: Areas required for the successful survival to adulthood by young animals.

Recovery: The return of an ecosystem to a defined condition after a disturbance.

Redds: Nests made in gravel (particularly by salmonids) for egg deposition consisting of a depression that is created and the covered.

Rehabilitation: Returning to a state of ecological productivity and useful structure, using techniques similar or homologus in concept; producing conditions more favorable to a group of organisms or species complex, especially that economically and aesthetically desirable flora and fauna, without achieving the undisturbed condition.

Resident fish: Fish species that complete their entire life cycle in freshwater.

Riffle: Stream habitat having a broken or choppy surface (white water), moderate or swift current, and shallow depth.

Riparian: Pertaining to the banks and other adjacent, terrestrial (as opposed to aquatic) environs of freshwater bodies, watercourses, and surface-emergent aquifers, whose imported waters provide soil moisture significantly in excess of that otherwise available through local precipitation – soil moisture to potentially support a mesic vegetation distinguishable from that of the adjacent more xeric upland.

Riparian Area: The area between a stream or other body of water and the adjacent upland identified by soil characteristics and distinctive vegetation. It includes wetlands and those portions of floodplains which support riparian vegetation.

Riparian Habitat Conservation Areas (RHCA): Portions of watersheds where riparian-dependent resources receive primary emphasis, and management activities are subject to specific standards and guidelines. The RHCAs include traditional riparian corridors, wetlands, intermittent headwater streams, and other areas where proper ecological functioning is crucial to maintenance of the stream's water, sediment, woody debris and nutrient delivery systems (USFS AND BLM 1995/ PACFISH)

Riparian Reserves: A land management designation for federally-administered lands within the range of the northern spotted owl (USFS and BLM 1994/ Northwest Forest Plan). The Riparian Reserves provide an area along all stream, wetlands, ponds, lakes, and unstable and potentially unstable areas where riparian-dependent resources receive primary emphasis.

Riparian Vegetation: Terrestrial vegetation that grows beside rivers, streams and other freshwater bodies and that depends on these water sources for soil moisture greater than would otherwise be available from local precipitation.

Riprap: Large rocks, broken concrete, or other structure used to stabilize streambanks and other slopes.

Rootwad: Exposed root system of an uprooted or washed-out tree.

Run: An area of swiftly flowing water, without surface agitation or waves, which approximates uniform flow and in which the slope of the water surface is roughly parallel to the overall gradient of the stream reach.

SaSI (Salmonid Stock Inventory): A list of Washington's naturally reproducing salmonid stocks and their origin, production type and status.

SASSI (Salmon and Steelhead Stock Inventory): former name of SaSI.

SSHIAP (Salmon, Steelhead Habitat Inventory and Assessment Project): A partnership based information system that characterizes distribution and freshwater habitat conditions of salmonid stocks in Washington.

Salmonid: Fish of the family salmonidae, including salmon, trout chars, and bull trout.

Salmon: Includes all species of the family Salmonid

Sediment: Material carried in suspension by water, which will eventually settle to the bottom.

Sedimentation: The process of subsidence and deposition of suspended matter carried in water by gravity; usually the result of the reduction in water velocity below the point at which it can transport the material in suspended form.

Side channel: Lateral channel with an axis of flow roughly parallel to the mainstem, which is fed by water from the mainstem; a braid of a river with flow appreciably lower than the main channel. Side channel habitat may exist either in well defined secondary (overflow) channels or in poorly defined watercourses flowing through partially submerged gravel bars and islands along the margins of the mainstem.

Sinuosity: Degree to which a stream channel curves or meanders laterally across the land surface. Can be determined by the ratio of the stream length to valley floor, or, the ratio of the channel length between two points on a channel to the straight line distance between the same points.

Slope: Water surface slope is determined by measuring the difference in water surface elevation per unit stream length. Typically measured through at least twenty channel widths or two meander wavelengths.

Slope stability: The degree to which a slope resists the downward pull of gravity.

Smolt: Juvenile salmonid, 1 or more years old, migrating seaward; a young anadromous trout, salmon, or char undergoing physiological changes that will allow it to change from life in freshwater to life in the sea. The smolt stage follows the parr stage. See *parr*.

Stock: Group of fish that is genetically self-sustaining and isolated geographically or temporally during reproduction. Generally, a local population of fish. More specifically, a local population – especially that of salmon, steelhead (rainbow trout), or other anadromous fish – that originates from specific watersheds as juveniles and generally returns to its birth streams to spawn as adults.

Stream Number: A unique six-digit numerical stream identifier, with the first two digits representing the WRIA and the last four digits representing the unique stream identifier from the WDF Stream Catalog (Williams et al. 1975) where available. For streams where the Stream Catalog does not provide a stream identified: (1) unassigned numbers in the sequence are used; or (2) an additional single-character alpha extension may be added to the end of the four-digit stream identifier for the next downstream numbered stream. Alpha extensions are generally used for tributaries to a numerically identified stream proceeding from downstream to upstream.

Stream Order: A classification system for streams based on the number of tributaries it has. The smallest unbranched tributary in a watershed is designated Order 1. A stream formed by the confluence of two order 1 streams is designated Order 2. A stream formed by the confluence of two order 2 streams is designated Order 3; and so on.

Stream Reach: a homogeneous segment of a drainage network characterized by uniform channel pattern, gradient, substrate and channel confinement.

Stream Types:

Type 1: All waters within their ordinary high-water mark as inventoried in "Shorelines of the State".

Type 2: All waters not classified as Type 1, with 20 feet or more between each bank's ordinary high water mark. Type 2 waters have high use and are important from a water quality standpoint for domestic water supplies, public recreation, or fish and wildlife uses.

Type 3: Waters that have 5 or more feet between each bank's ordinary high water mark, and which have a moderate to slight use and are more moderately important from a water quality standpoint for domestic use, public recreation and fish and wildlife habitat.

Type 4: Waters that have 2 or more feet between each bank's ordinary high water mark. Their significance lies in their influence on water quality of larger water types downstream. Type 4 streams may be perennial or intermittent.

Type 5: All other waters, in natural water courses, including streams with or without a well-defined channel, areas of perennial or intermittent seepage, and natural sinks. Drainage ways having a short period of spring runoff are also considered to be Type 5.

Subwatershed: One of the smaller watersheds that combine to form a larger watershed.

Supplementation: the collection, rearing, and release of locally adapted salmon in ways that promote ecologic and genetic compatibility with the naturally produced fish.

Terrace: Abandoned floodplain.

Thalweg: The path of maximum depth in a river or stream.

Watershed: An area so sloped as to drain a river and all its tributaries to a single point or particular area. The total area above a given point on a watercourse that contributes water to its flow.

Watershed restoration: Reestablishing the structure and function of an ecosystem, including its natural diversity; a comprehensive, long-term program to return watershed health, riparian ecosystems, and fish habitats to a close approximation of their condition prior to human disturbance.

Watershed-scale approach: Consideration of the entire watershed in a project or plan.

Weir: Device across a stream to divert fish into a trap or to raise the water level or divert its flow. Also a notch or depression in a dam or other water barrier through which the flow of water is measured or regulated.

Width-depth ratio: Describes the dimension and shape factor as the ratio of bankfull channel width to bankfull mean depth.

Wild Stock: A stock that is sustained by natural spawning and rearing in the natural habitat regardless.